System Control

Fall 2014

Professor Kyongsu Yi

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Vehicle Dynamics and Control Laboratory
Seoul National University

Lecture 1: Course Overview

Instructor: 이경수 Professor Kyongsu Yi
301-1502
Tel: 880-1941 Email:kyi@snu.ac.kr
http:// vdcl.snu.ac.kr

Lectures: **Tu/Th** 11:00-12:15 @301-301

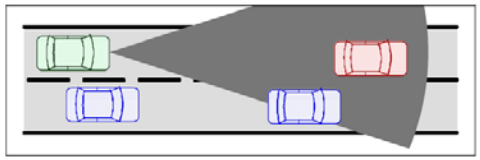
Office hours: **Tu/Th** 10:00 to 11:00 or by appointment

Lecture 1:

Objective: To provide an overview of system control, basic concepts, controller design methods and applications to engineering systems

Mathematical model, analysis and prediction of the dynamics of systems, state equation and system stability, linear control systems, PID control, controller design in the frequency and time domains

Lecture 1:



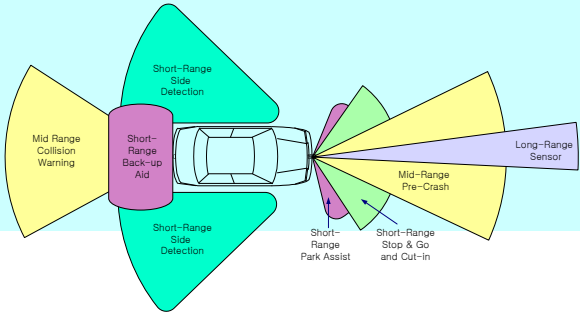
Grading: **Homework 15%, Class attendance 10%**
Midterm Exam 30%, Final exam 45%
(과제 제출일에 과제관련 10 minutes 퀴즈를 보고 퀴즈 성적으로 10%반영)
Students absent in a class without instructor's permission prior to the class would be failed.

Homework: **Students will turn in before the end of the class on the due date. Late homework will not be accepted. All homework assignments are to be completed on your own. You are allowed to consult with other students during the conceptualization of a problem but all written and programming work are to be generated by yourself.**

Lecture 1:

Exam:

- **75-minute midterm exam on October 21 (Tu) in class, 11:00-12:10**
- **90+ minute final exam on December 11 (Th) in class, 11:00-13:00 or 19:00-21:00**



Major Course Contents

In this course we will learn how to model and control engineering systems.

Key issues are: Understanding the underlying physics and being able to construct models and design controllers to analyze, predict and control engineering systems.

References

1. K. Ogata, **Modern control engineering, 5th ed.,** Prentice Hall, 2010.

2. G. Franklin et al., **Feedback control of dynamic systems**, 6th ed., Prentice Hall, 2010.

3. S. Shinners, **Modern control system theory and design,** Wiley interscience, 1998.

4. W. Palm, **System dynamics, 2nd ed., McGraw-Hill**, 2010.

수강생참고사항

1. 과제는 제출기일 수업시간에 제출해야함

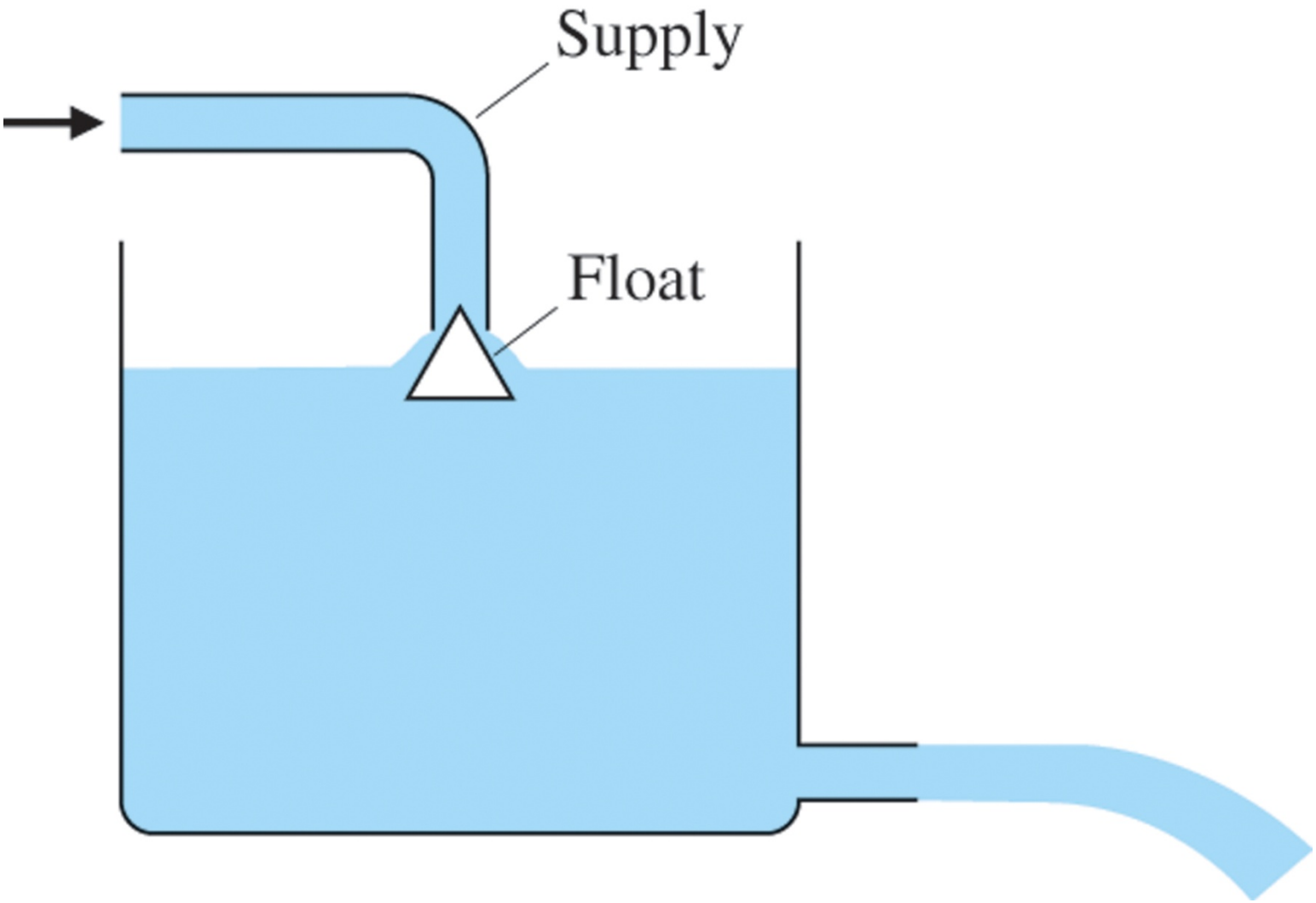
2. 강의에 참석하지 못하는 경우 담당교수에게 사전 사유서 제출해야함. 사전에 사유서를 제출하지 못하는 사정이 있는 경우는 사후에 사유서를 제출하는 것도 인정함. 사유서 제출없이 수업 결석한 경우 -5

3. 강의 계획은 수업 진행 상황에 따라 변경될 수 있음

4. ETL 사용 장려함 (http://etl.snu.ac.kr)
   - Homework 공고
   - 강의 자료 공고
   - 질의 응답
   - TA 문의사항

Control Systems

Early historical control of liquid level and flow



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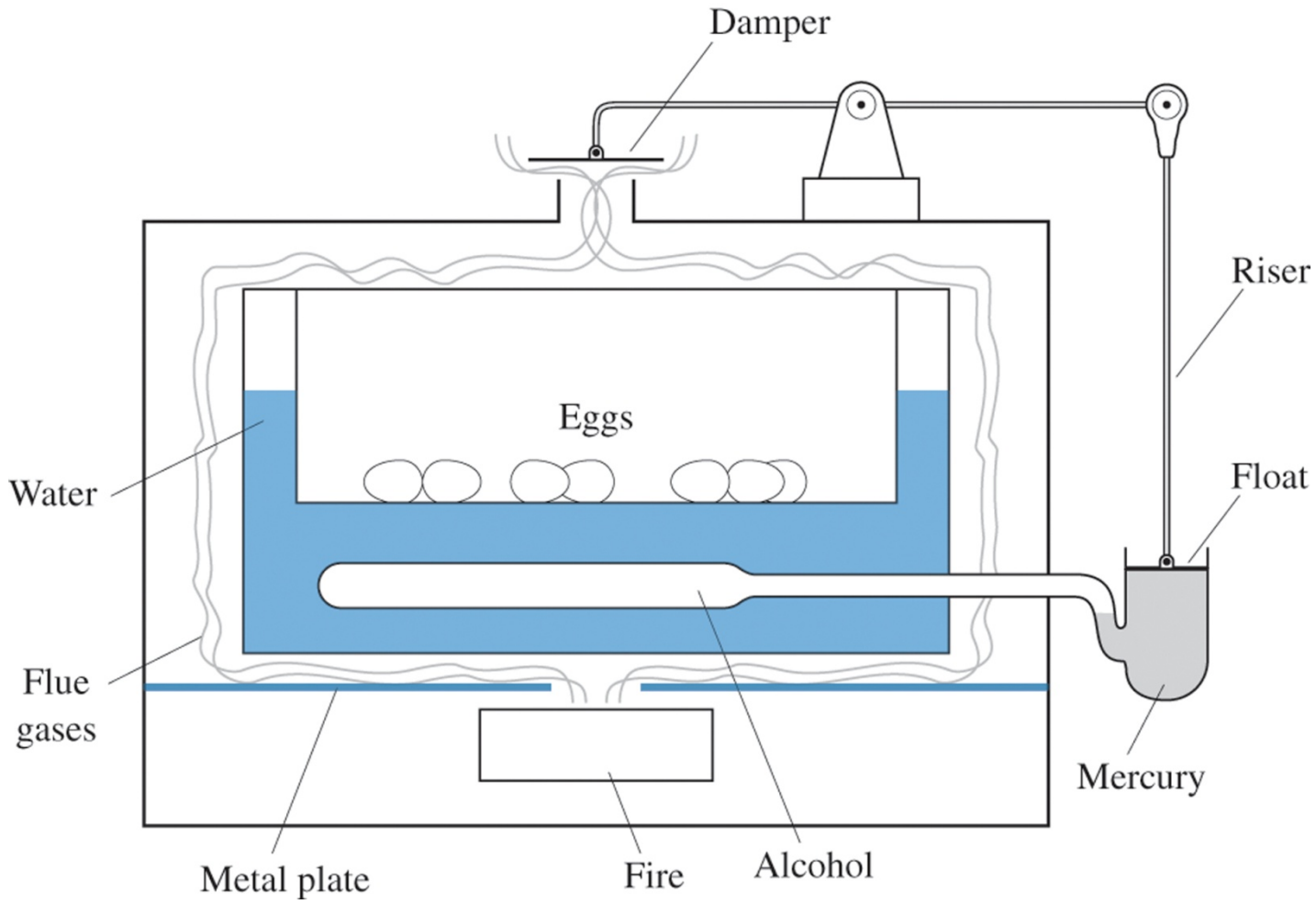
Drebbel's incubator for hatching chicken eggs

Source: Adapted from Mayr, 1970



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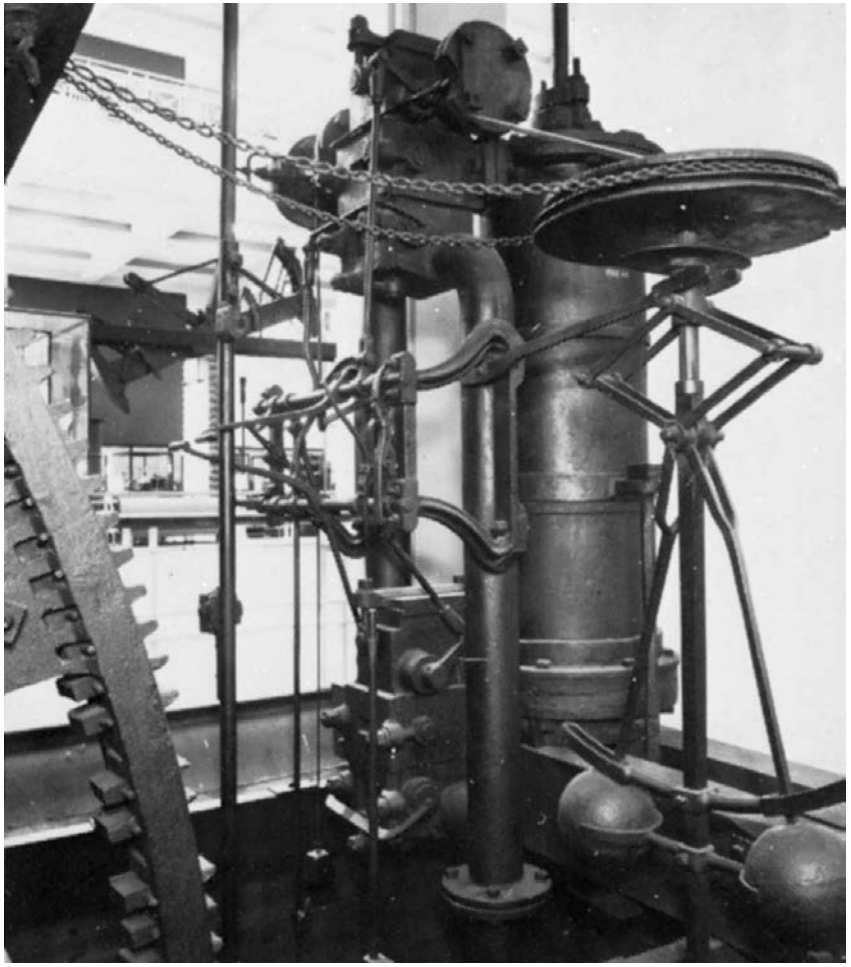
the fly-ball governor

Source: British Crown Copyright, Science Museum, London



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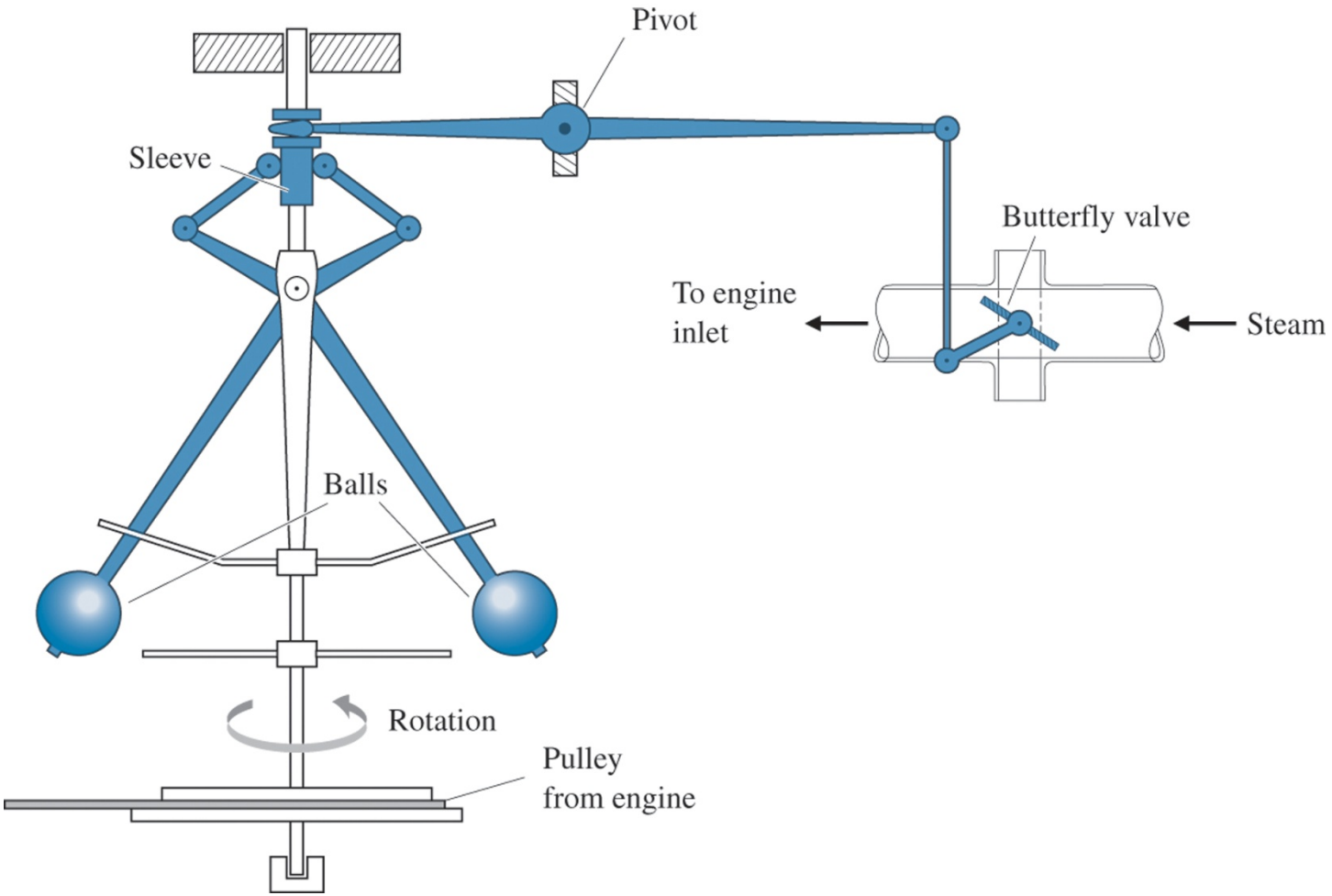
Operating parts of a fly-ball governor



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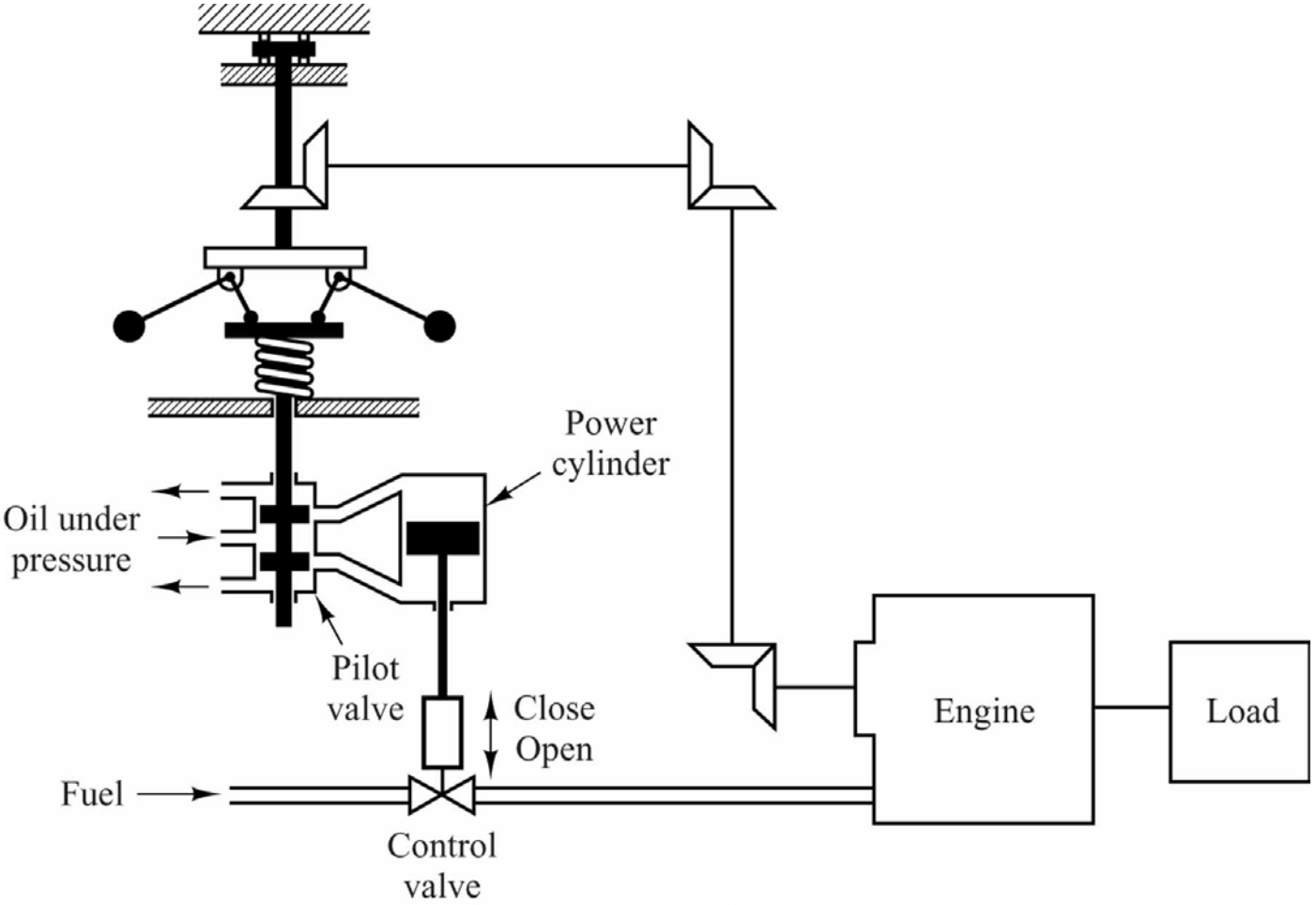
Engine Speed control system.



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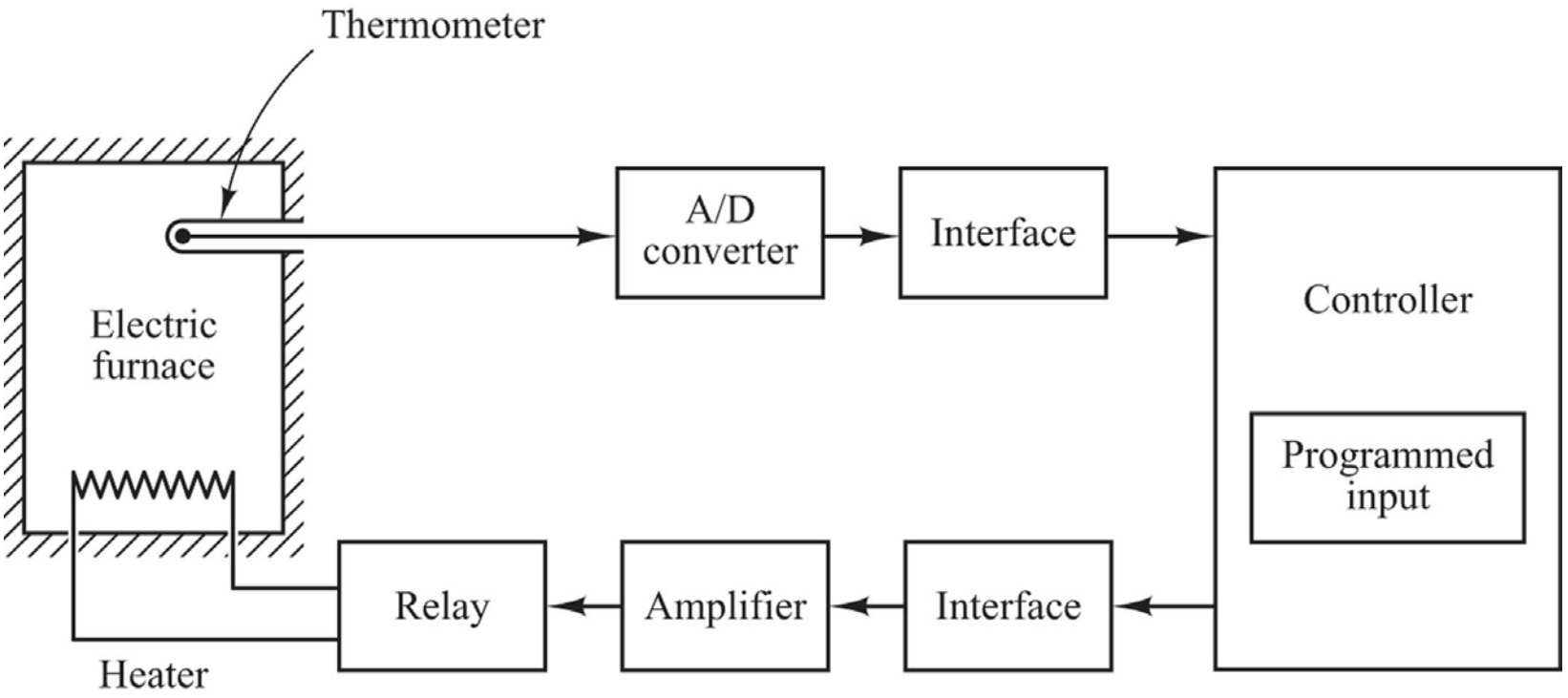
Temperature control system.



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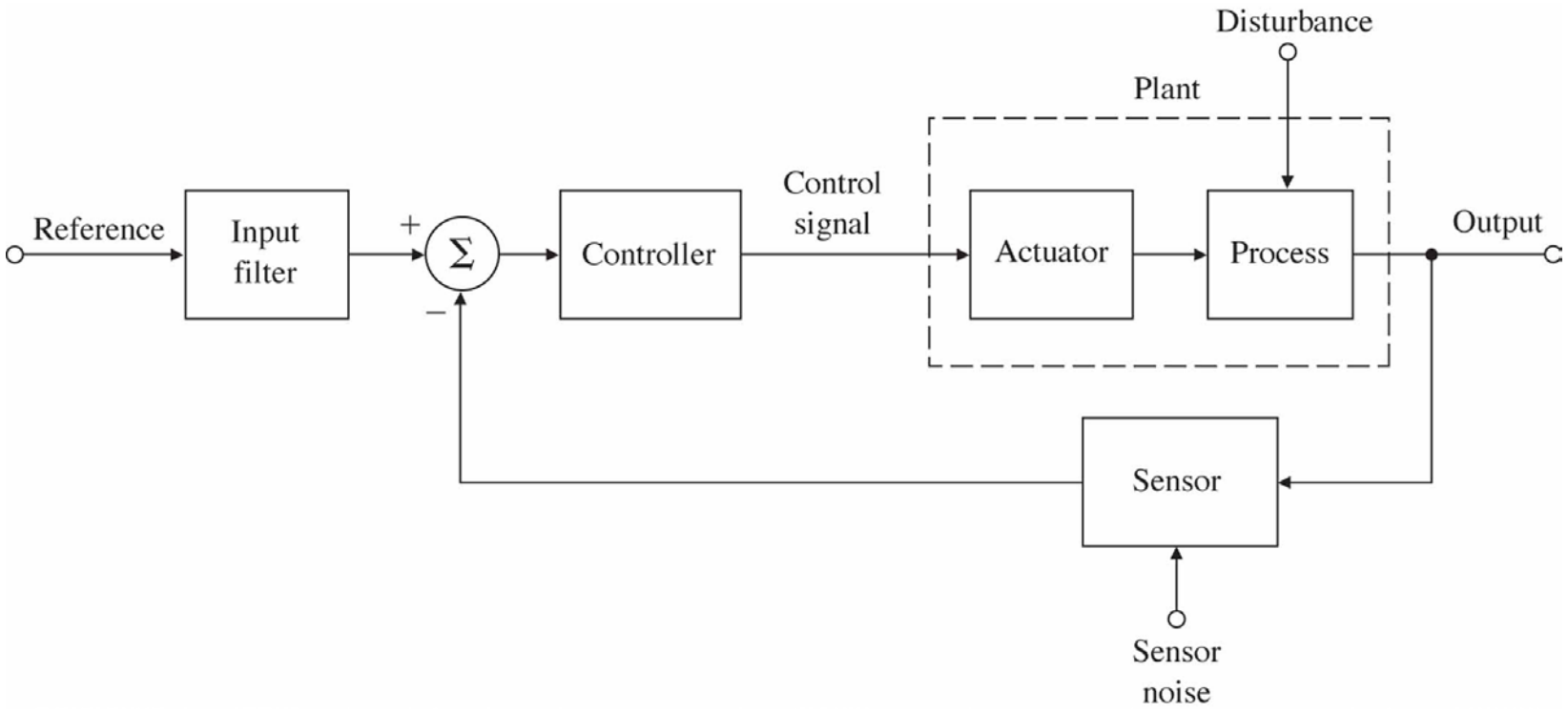
Component block diagram of an elementary feedback control



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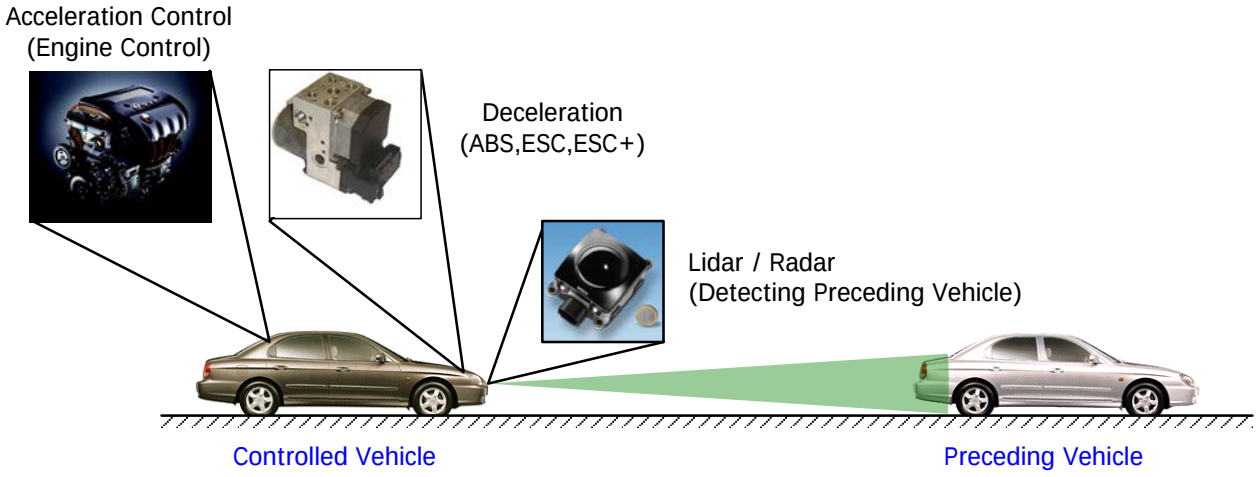
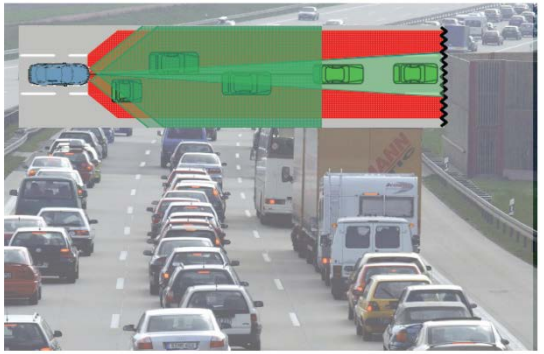
Smart Cruise Control

Hyundai Motor Company, GENESIS, in 2008



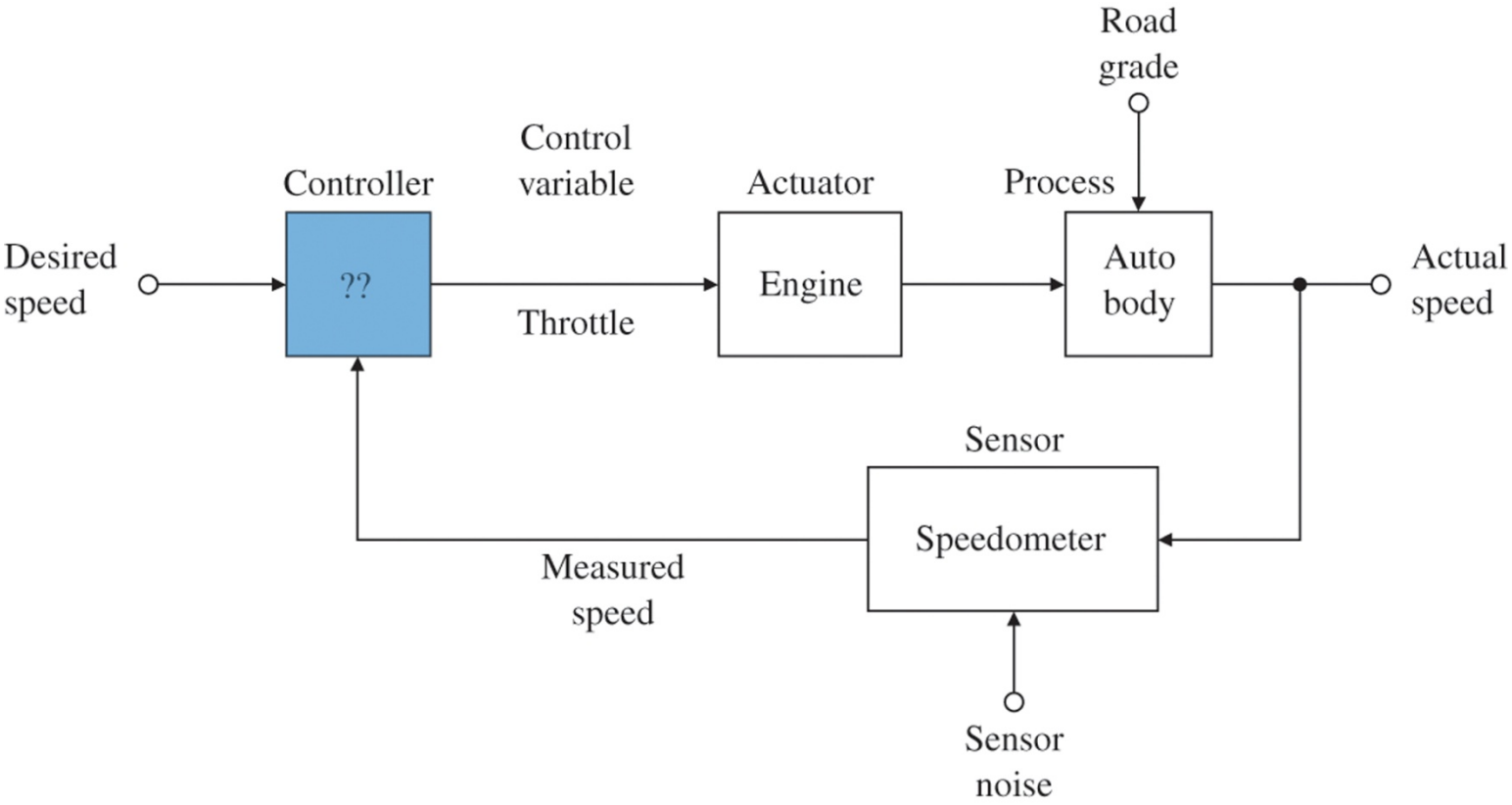


The infrared ranging system

Continental
"Car Safety" for tailgater
2009 Volvo XC60
20 ft sweep with three infrared beams

The greatest danger for accidents is in normal city driving- 75% of rear end collisions occur between vehicles traveling at less than 20 mph.

Component block diagram of automobile cruise control



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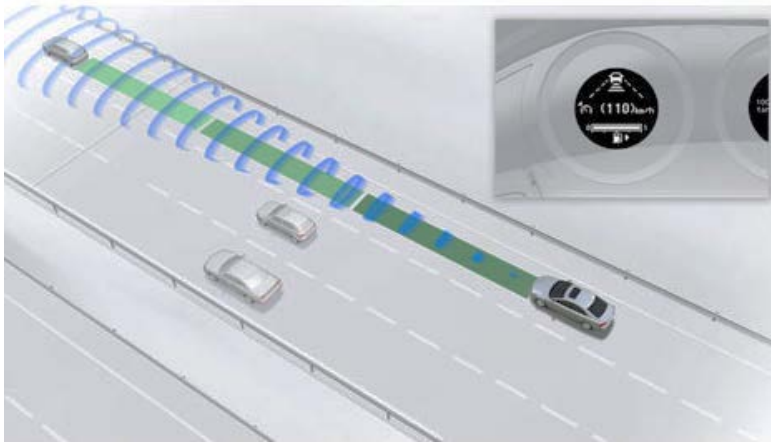
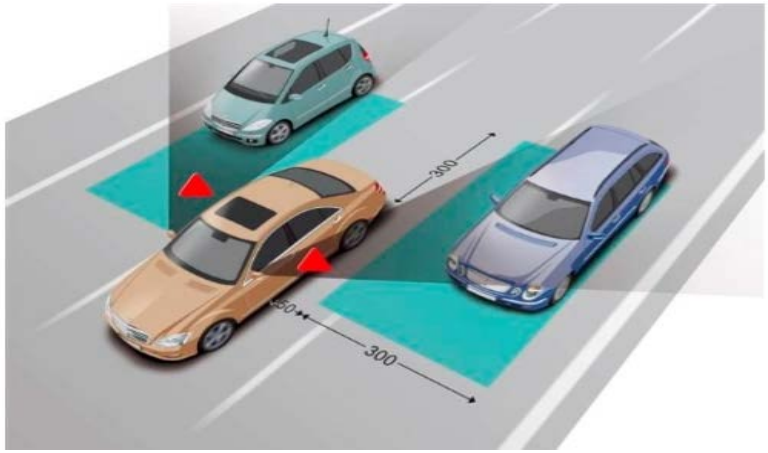
Driver Assistance Systems



Smart Cruise Control System

Lane Keeping Assist System

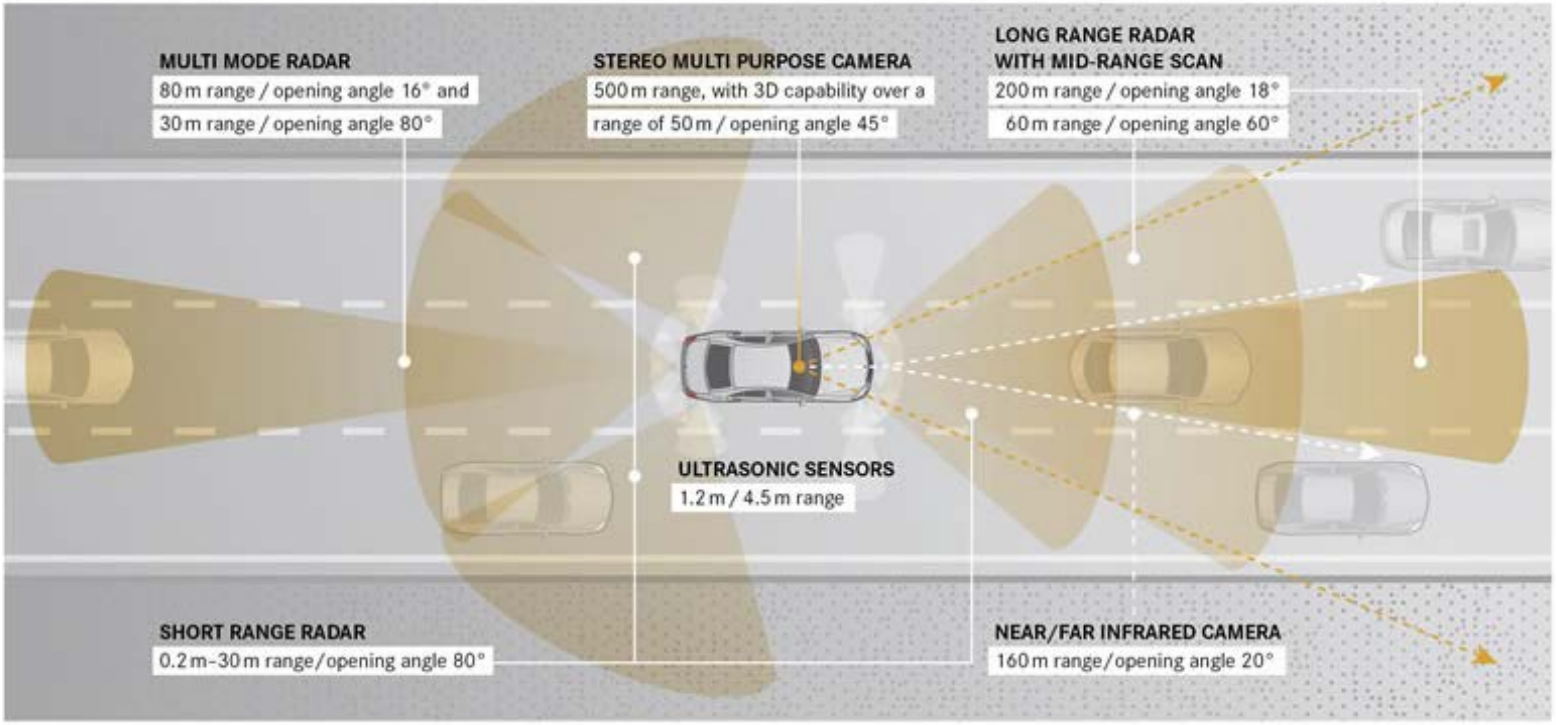


Blind Spot Detection System

New Mercedes S Class

Radar, stereo camera and ultrasonic systems

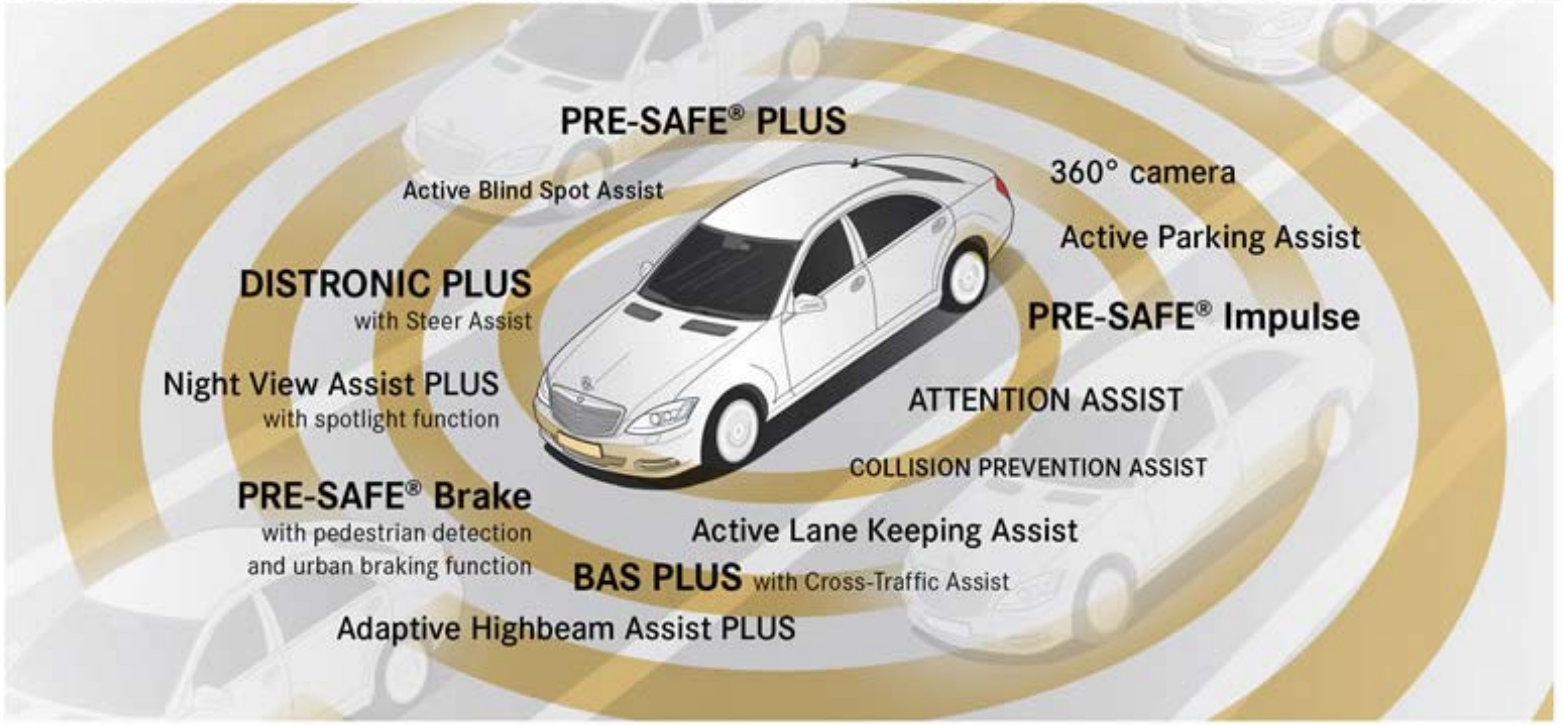
More sensors – more protection



http://www.emercedesbenz.com/autos/mercedes-benz/s-class/top-20-mercedes-benz-assistance-programs/

New Mercedes S Class

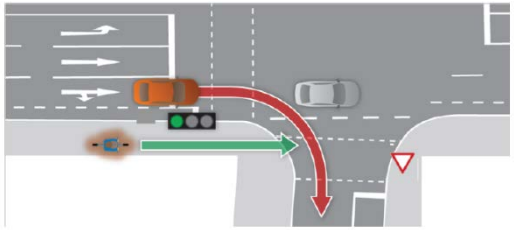
◢ **Intelligent Drive – all-round protection:**
Assistance systems now with markedly enhanced performance capabilities



http://www.emercedesbenz.com/autos/mercedes-benz/s-class/top-20-mercedes-benz-assistance-programs/

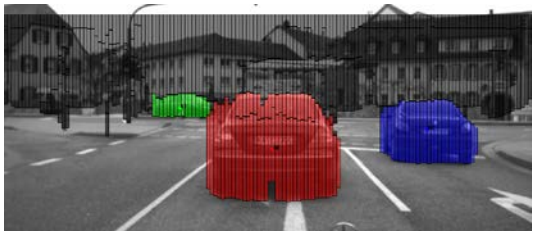
On going developments: safety technologies

- Wireless ped detection



- Path planning for Dynamic Driving Task

- Stereo vision



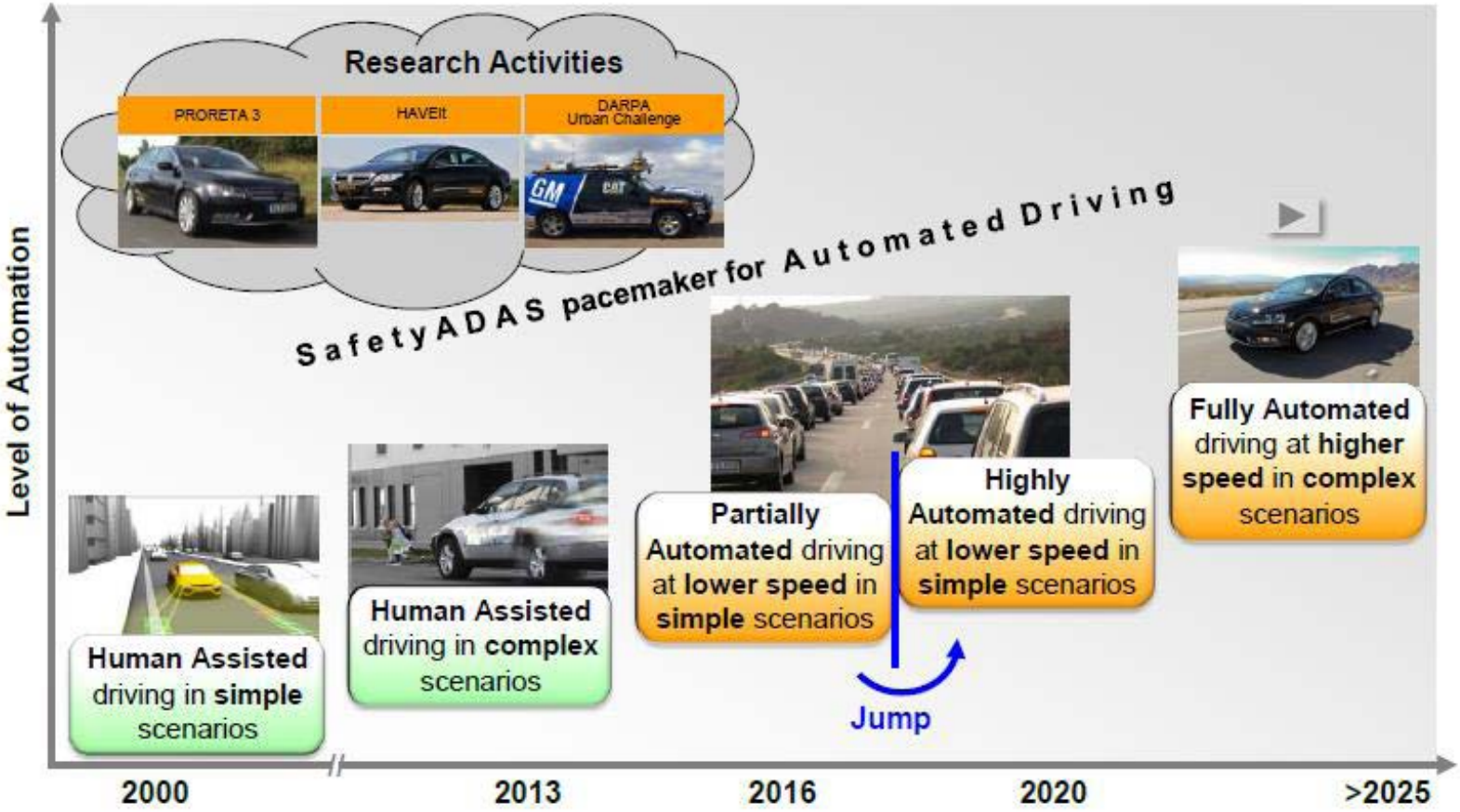
From Stixels to Objects
Friedrich Erbs1, Beate Schwarz2 and Uwe Franke1
IV 2013

- Robust Vehicle Control for Automated Driving with Uncertainties

<Active Safety for Vulnerable Road Users based on Smartphone Position Data, BMW, Karlsruhe Univ. IV 2013>

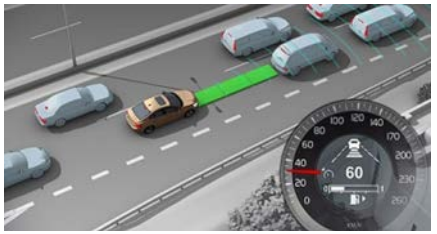
2013 Conti, Bosch, GM, Ford, BMW, Benz, Volkswagen

From Assisted Driving to Automated Driving
Roadmap

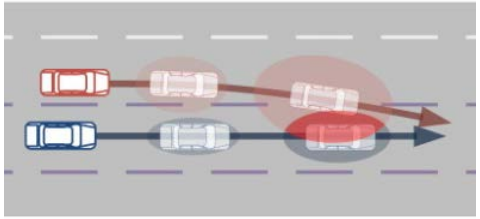


Level 4: Automated Driving

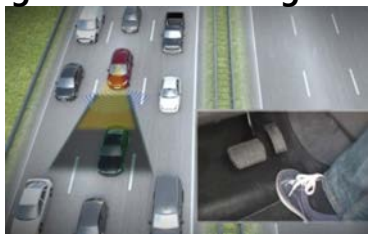
- Close-to-market Sensors
- Integrated Smart Safety
  - manual/autonomous
  - obstacle/target detection and tracking
  - free-space generation
  - throttle/brake/steering control



Smart Cruise Control



Integrated Risk Management



Traffic Jam Assistance

Evasive Steering

Total Number of Control Module=76

Complete structure network V240 maximum equipment

CAN CLASS B

1. Driver-side SAM c. m. with fuse and relay m.
2. Passenger-side SAM c. m. with fuse and relay m.
3. Rear SAM c. m. with fuse and relay m. 1
4. Rear SAM c. m. with fuse and relay m. 2
5. Left front seat c. m.
6. Right front seat c. m.
7. Left rear seat c. m.
8. Right rear seat c.m.
9. Left front door c. m.
10. Right front door c. m.
11. Left rear door c. m.
12. Right rear door c. m.
13. Partition wall c. m.
14. Front overhead control panel c. m.
15. Center roof node c. m.
16. FCP (VBF) c. m.
17. RCP (HBF) c. m.
18. EIS (EZS) control m.
19. Instrument cluster
20. Steering- column m.
21. AAC (KLA) pushbutton c. m.
22. Rear AC control and operating m.
24. Audio gateway c. m.
25. PTS c. m.
27. TPC (RDK) c. m.
28. PSE c. m. (combined)
29. TLC (HDS) c. m.
30. Central gateway c. m.
31. Airbag c. m. (Armada 20)
32. Special vehicle multifunction c. m. (SVMCM [MSS])
33. Vehicle power supply c. m.
34. Steering wheel heating converter
35. Independent car heater
36. Left rear closing assist c. m.
37. Right rear closing assist c. m.

CAN CLASS C

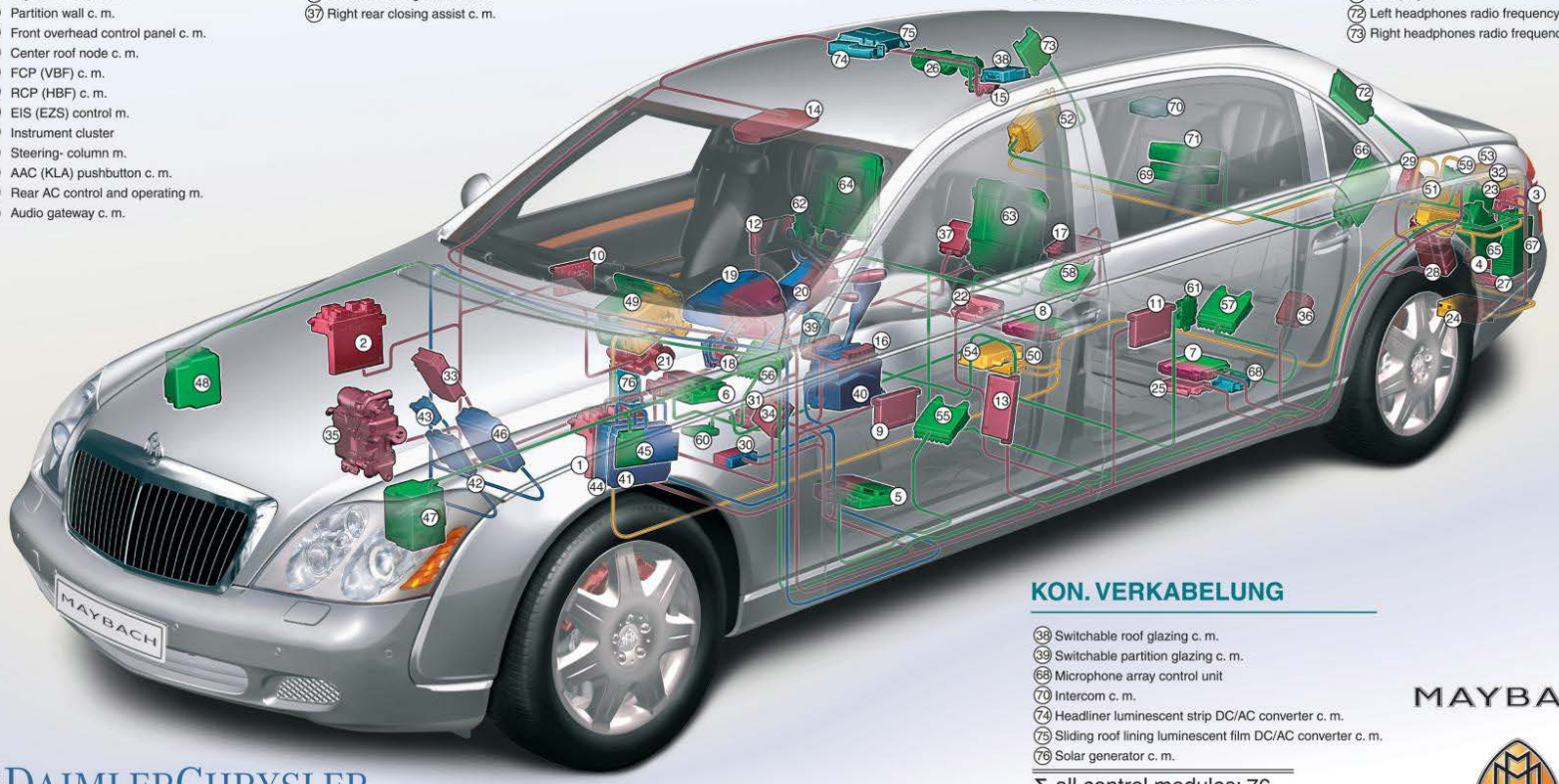
18. EIS (EZS) c. m.
19. Instrument cluster
20. Steering- column m.
30. Central gateway c. m.
40. Electronic selector lever module c. m.
41. AIRmatic with ADS c. m. (SLF)
42. DTR c. m.
43. Headlamp range adjustment c. m.
44. ME-SFI (ME) c. m.
45. Twin- Sensotronic Brake System (FSG)
46. ETC (EGS) c. m.

MOST-BUS

24. Audio gateway c. m.
49. Headunit
50. Voice control system control unit
51. TV-Tuner MOST
52. Sound amplifier
53. Navigation processor
54. Front telecom. control m. (CP1)

PRIVATE-BUS

5. Left front seat c. m.
6. Right front seat c. m.
7. Left rear seat c. m.
8. Right rear seat c. m.
23. TV-Tuner CAN
26. Roof instument
45. Twin- Sensotronic Brake System (FSG)
47. Twin- Sensotronic Brake System (ASG 1)
48. Twin- Sensotronic Brake System (ASG 2)
55. Left front multicontour backrest c. m.
56. Right front multicontour backrest c. m.
57. Left rear multicontour backrest c. m.
58. Right rear multicontour backrest c. m.
59. Rear m. Keyless Go c. m.
60. Interior m. Keyless Go c. m.
61. Left rear door Keyless Go c. m.
62. Right rear door Keyless Go c. m.
63. Left rear display
64. Right rear display
65. Rear telecommunications c. m. (CP2)
66. Surround amplifier c. m.
67. Audio/video controller c. m.
69. CD player with changer
71. DVD player
72. Left headphones radio frequency transmitter
73. Right headphones radio frequency transmitter



KON. VERKABELUNG

38. Switchable roof glazing c. m.
39. Switchable partition glazing c. m.
68. Microphone array control unit
70. Intercom c. m.
74. Headliner luminescent strip DC/AC converter c. m.
75. Sliding roof lining luminescent film DC/AC converter c. m.
76. Solar generator c. m.

Σ all control modules: 76

c. m. = control module

MAYBACH

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Control Systems

- **An aircraft**
- **A head positioner for a computer hard disk**
- **A vehicle**
- **An engine/transmission/brake/ steering/ suspension systems**
- **An electric rice cooker**
- **An excavator**
- **A room air conditioner**
- **A refrigerator**
- **Electric power plant**
- **Robots**
- **Chemical and Manufacturing Process Control: temperature; pressure; flow rate; concentration of a chemical; moisture contents; thickness.**

- **……**

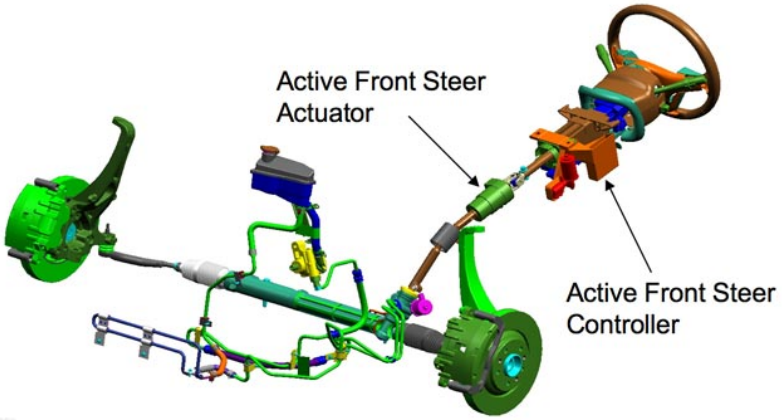
Nothing works without Control !!

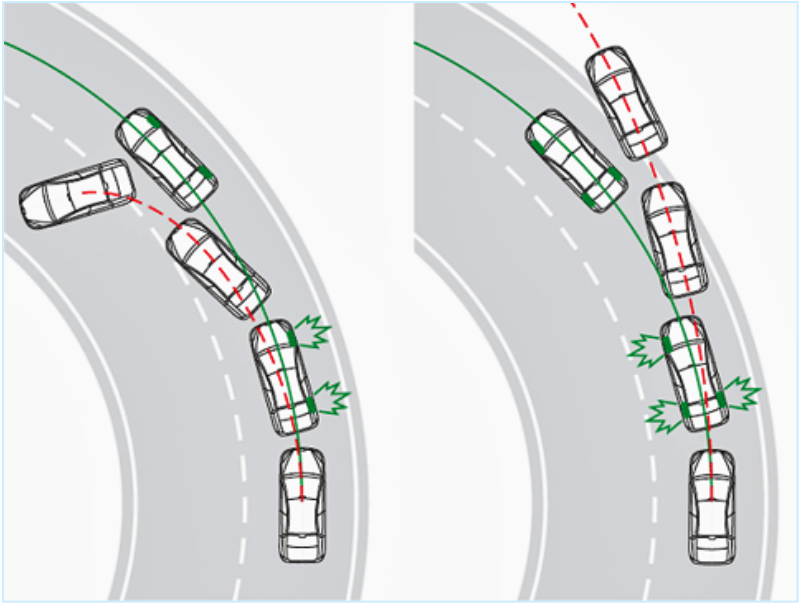
END of Course Overview

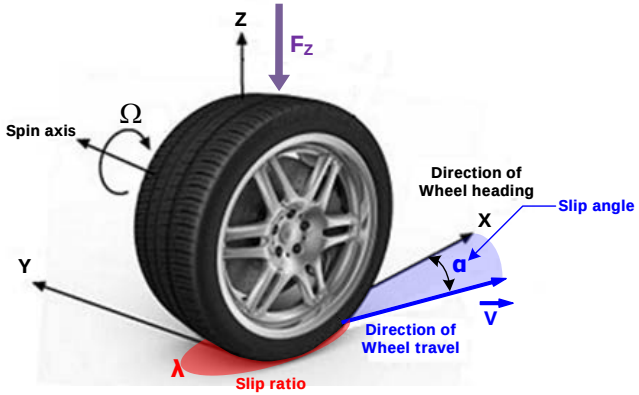
ESC

Electronic Stability Control

Cadillac STS – Active Front Steer System Diagram

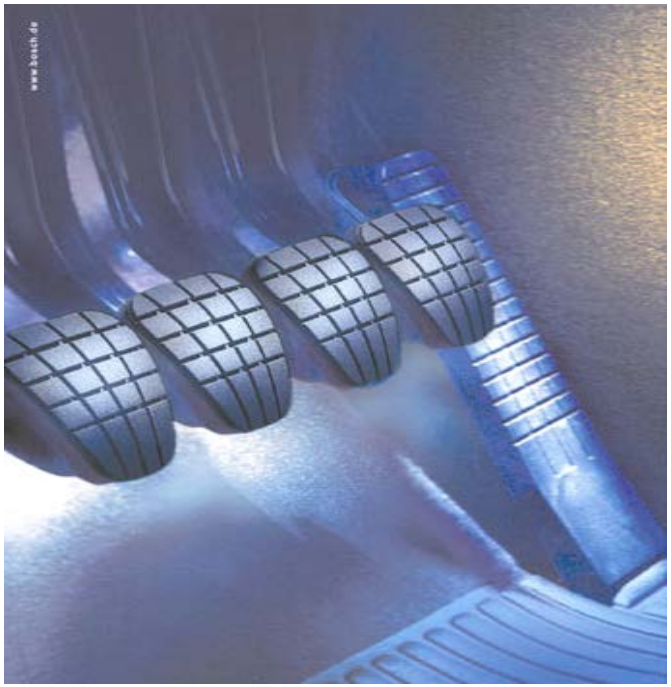






ESC: 4 wheel independent braking

Can you brake hard on the front wheel, softly on the back left wheel and, at the same time, accelerate the back right wheel to stop the rear of your car losing control in a bend?



VSC (Vehicle Stability Control)

An innovative safety system

- **Actively supporting the driver**
- **Enhanced driving stability in situations with critical vehicle dynamics**

• VSC (Vehicle Stability Control) a standard for all the manufactured vehicles by Mercedes Benz since 2002

• it is mandated by legislation that all vehicles should be equipped with ESC in 2012 in USA.

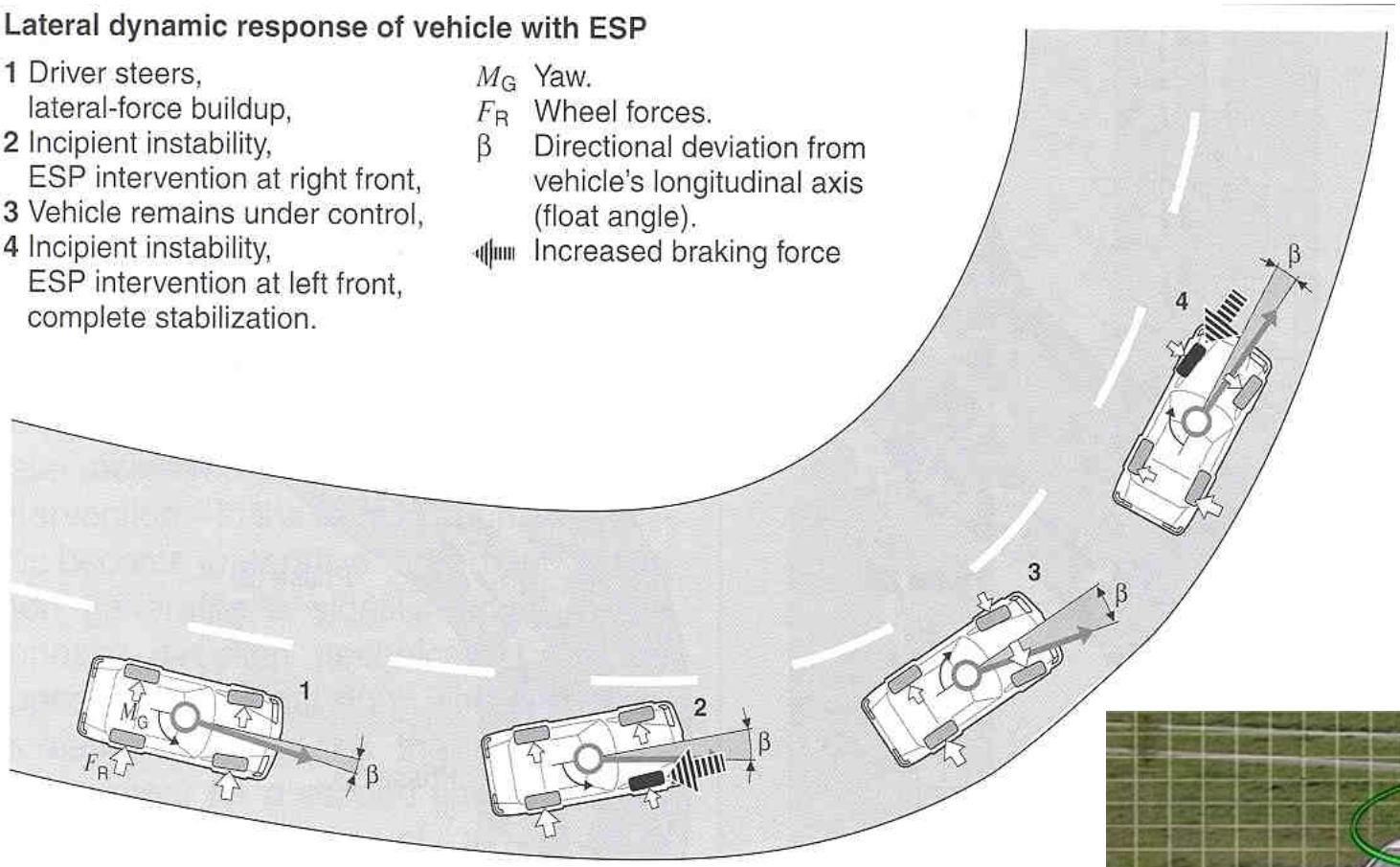
• VSC, an active safety system, can significantly increase vehicle safety and projected 5,300 to 9,600 highway deaths annually can be prevented by 100% fitment of VSC.

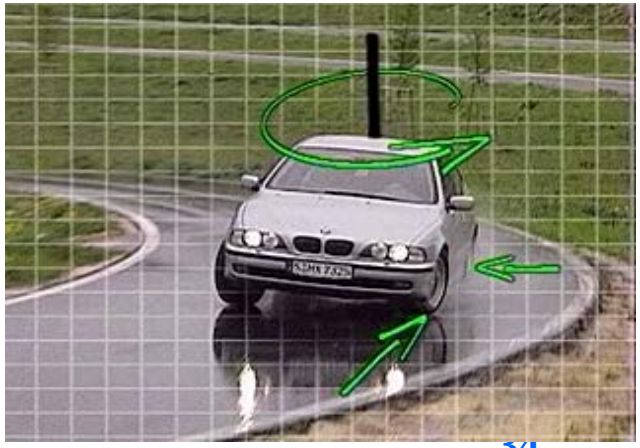
ESP (Electronic Stability Program)

Lateral dynamic response of vehicle with ESP

1 Driver steers, lateral-force buildup,
2 Incipient instability, ESP intervention at right front,
3 Vehicle remains under control,
4 Incipient instability, ESP intervention at left front, complete stabilization.

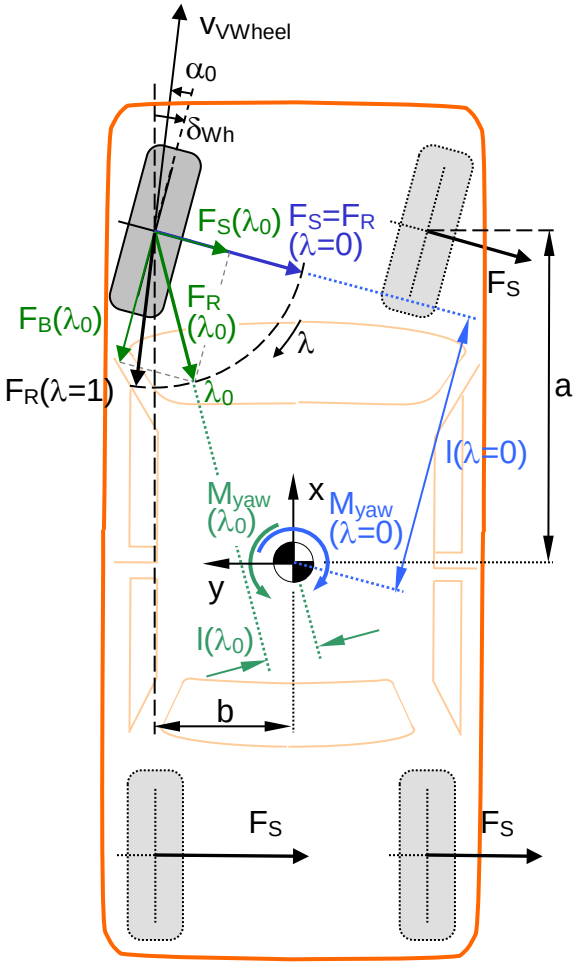
M_G Yaw.
F_R Wheel forces.
β Directional deviation from vehicle's longitudinal axis (float angle).
Increased braking force





Unified Chassis Control (UCC)

- Vehicle Lateral Motion (Dynamic Equations)



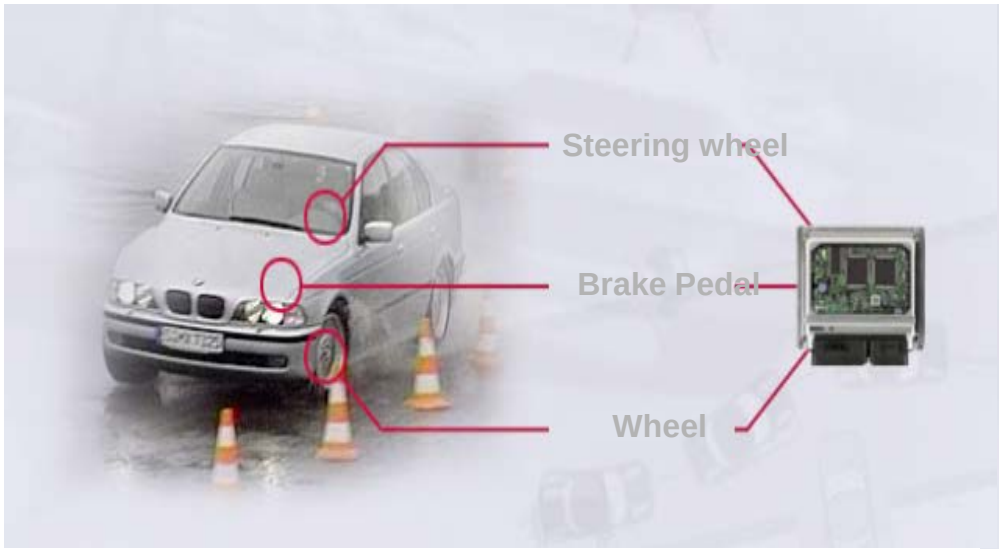
$$m(\dot{v}_x - \gamma v_y) = F_{xr} + F_{xf}\cos\delta_f - F_{yf}\sin\delta_f$$

$$m(\dot{v}_y + \gamma v_x) = F_{yr} + F_{yf}\cos\delta_f - F_{xf}\sin\delta_f$$

$$I_z\dot{\gamma} = l_f F_{yf}\cos\delta_f - l_r F_{yr} - l_f F_{xf}\sin\delta_f \ldots$$

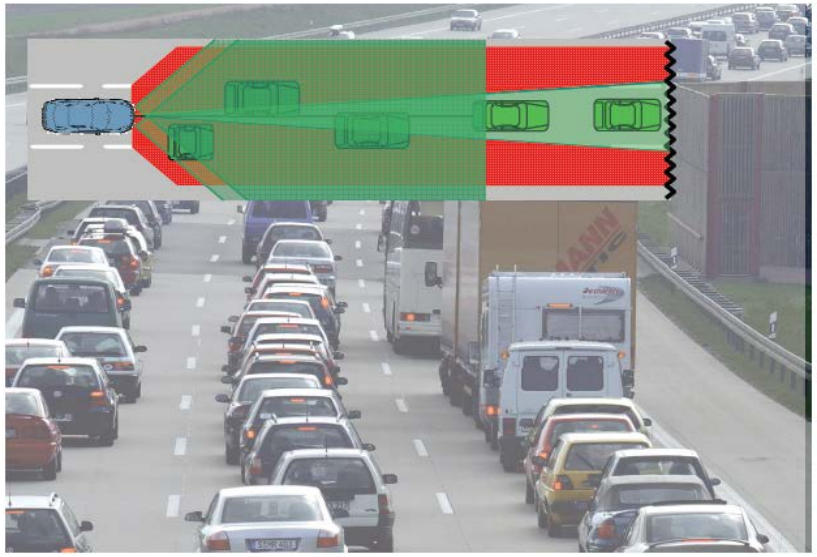
$$+\frac{d}{2}(\Delta F_{xr} + \Delta F_{xf}\cos\delta_f)$$

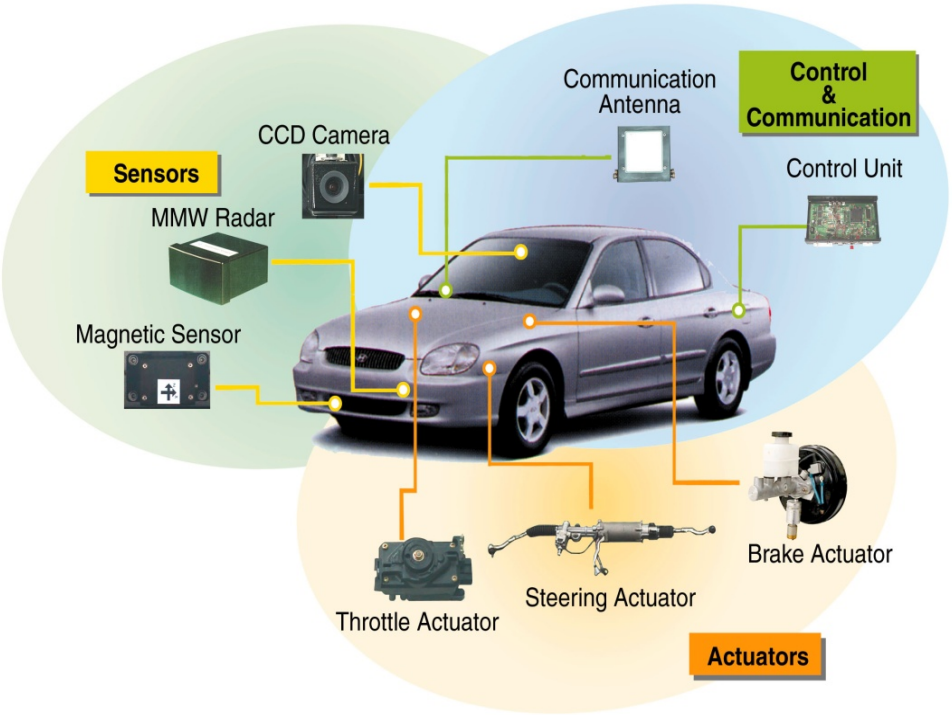
Vehicle Stability Control Systems



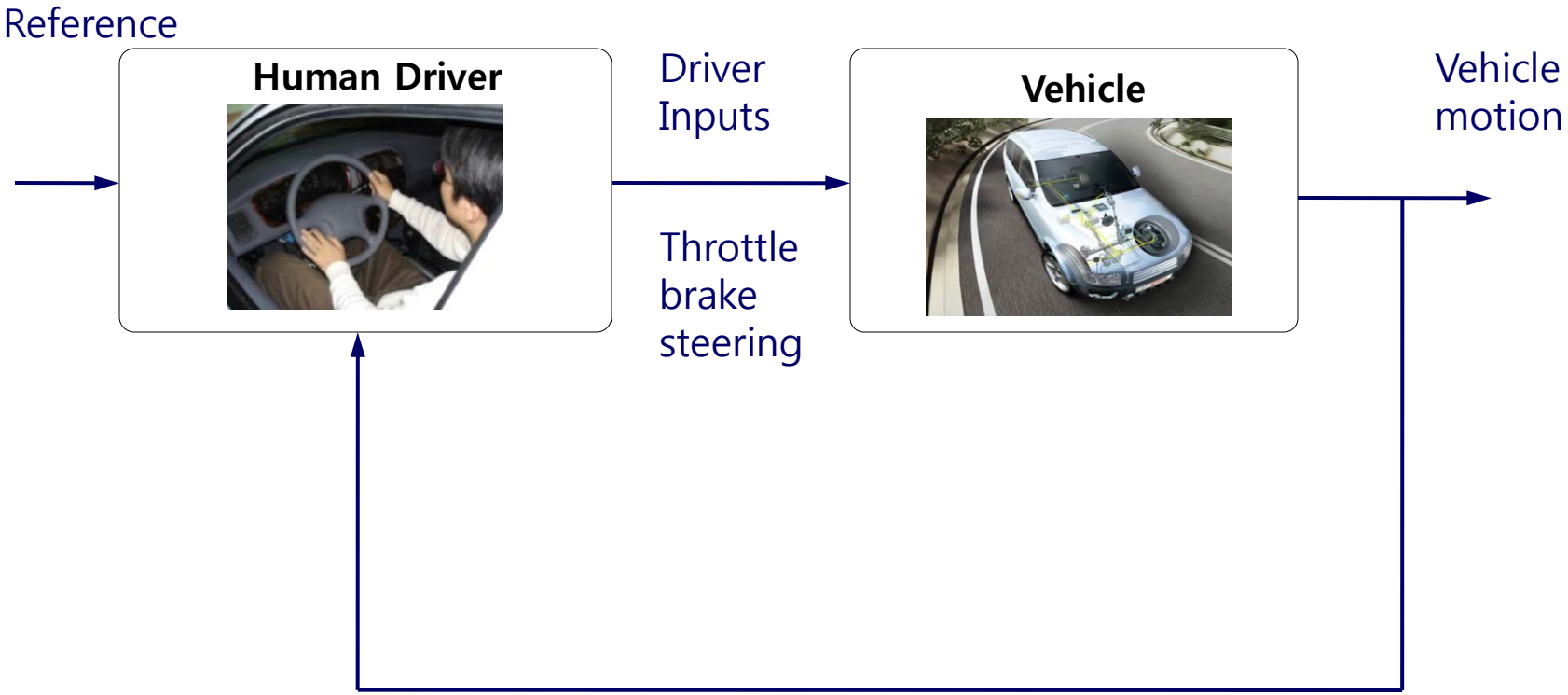
Smart Cruise Control

Adaptive Cruise Control with Stop & Go:
ACC S&G.

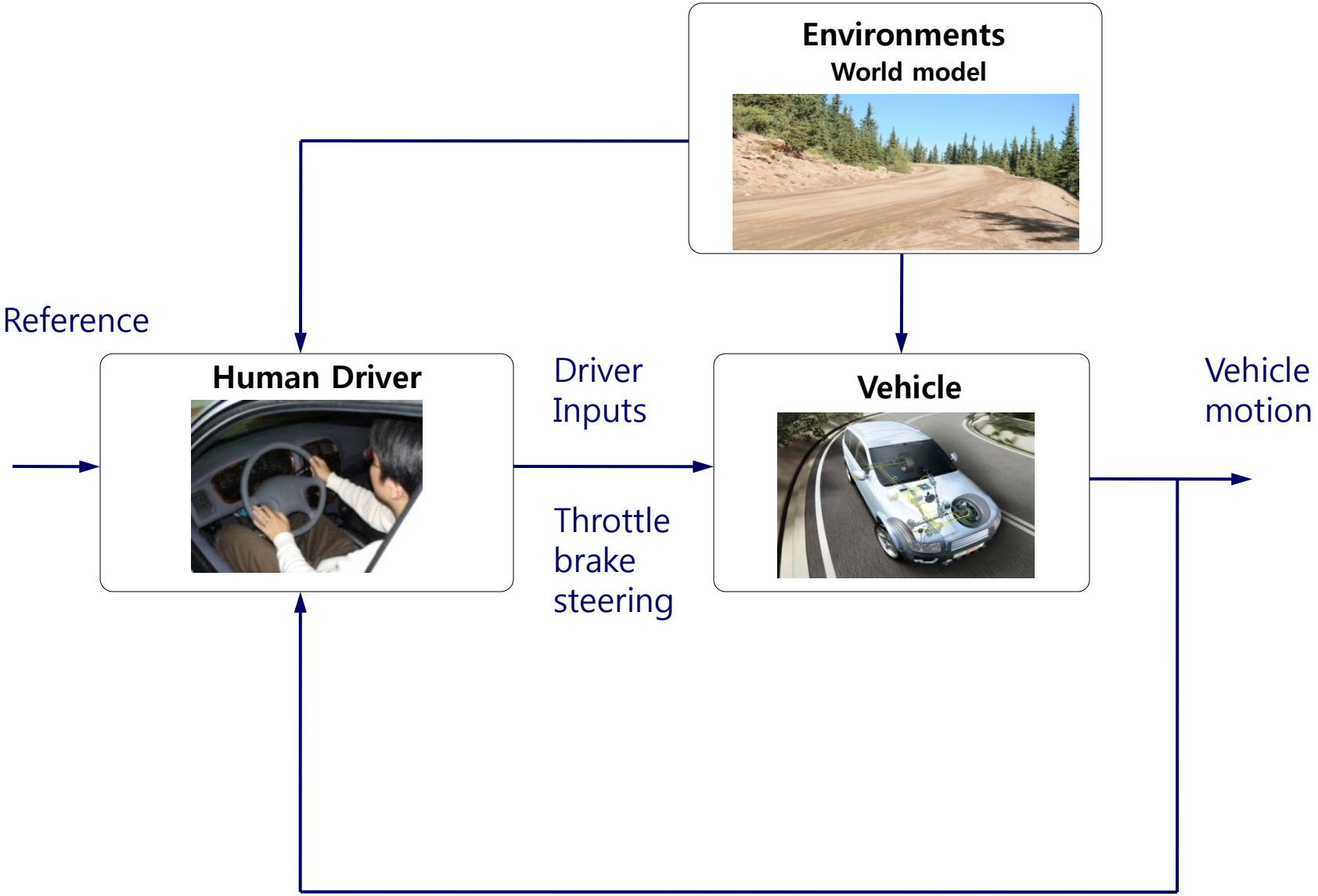




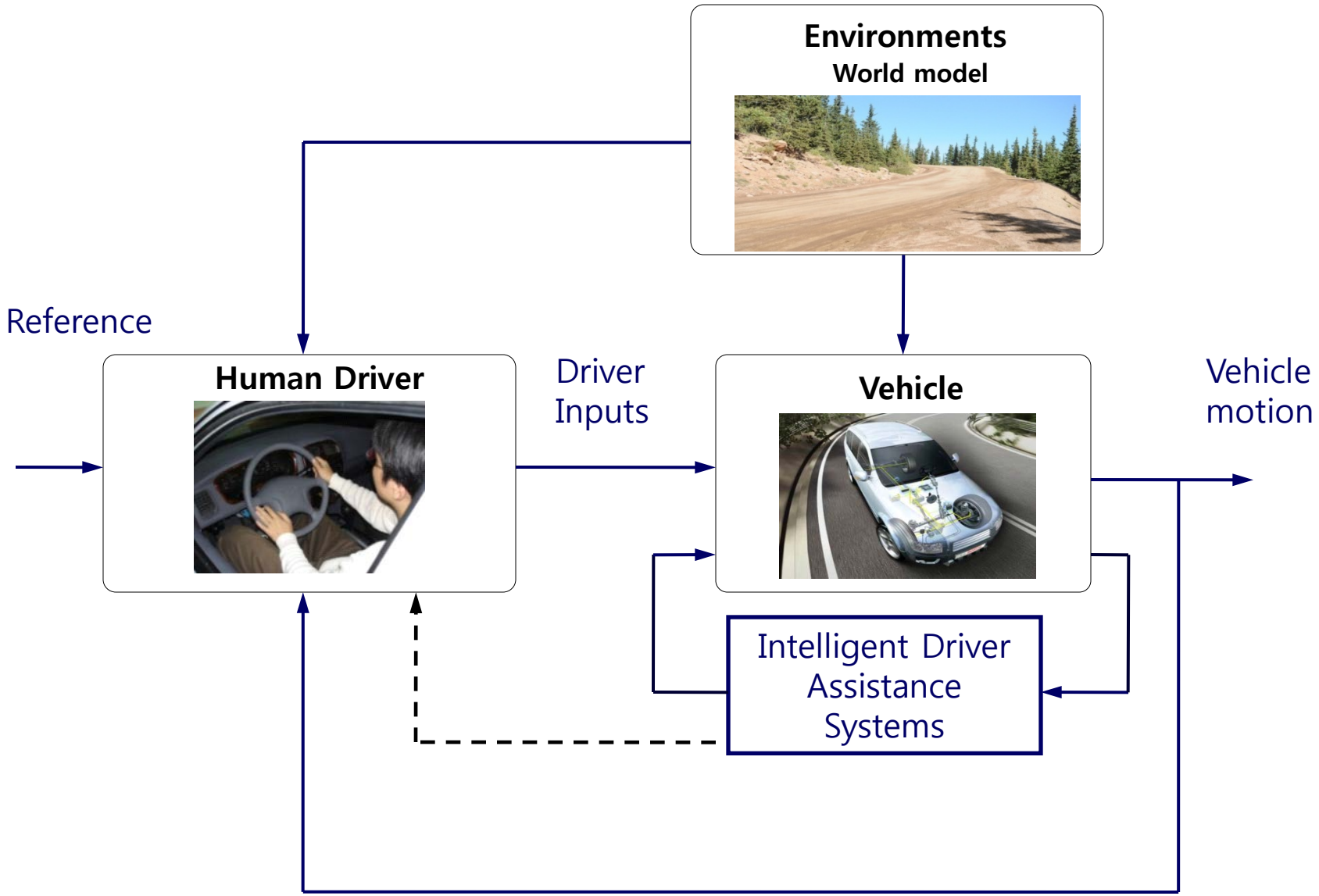
Vehicle-Driver Systems



Vehicle-Driver Systems

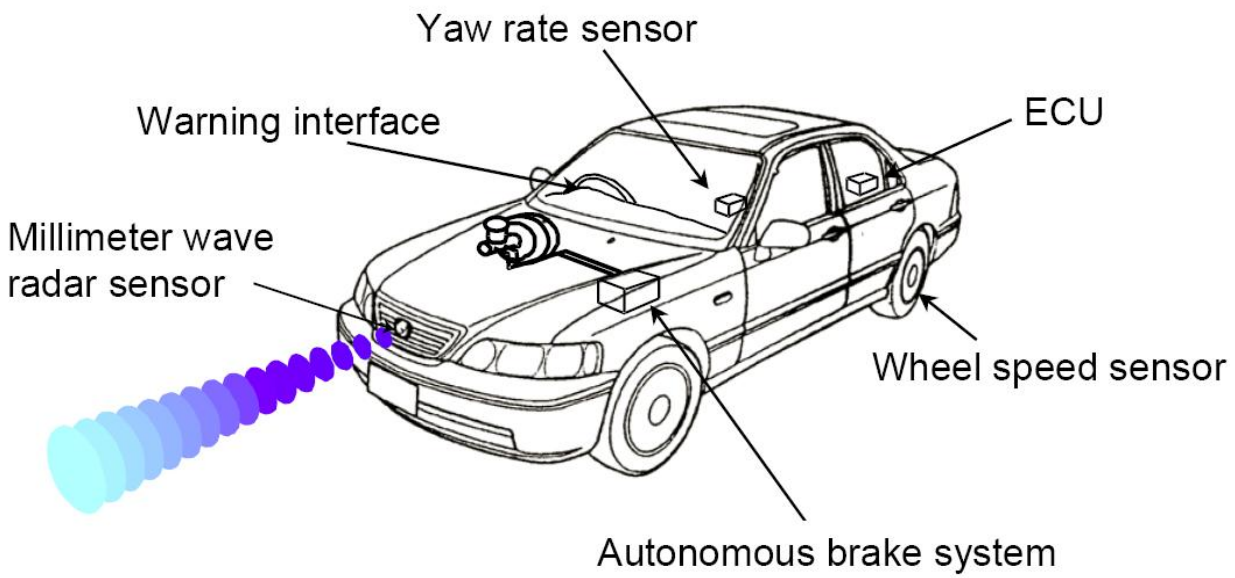


Vehicle-Driver-Control Systems



END of Course Overview

CMS (Collision Mitigation brake Systems, Honda, 2003)



1. effective reducing rear-end collision

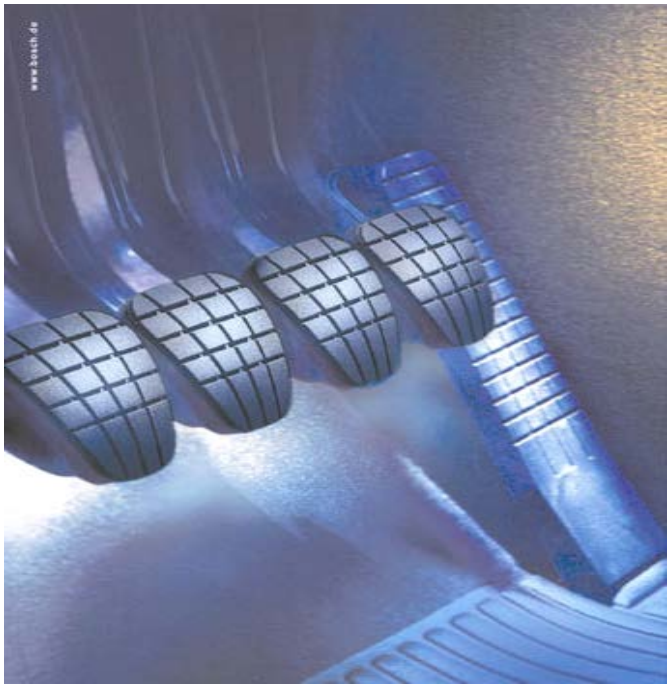
2. prevent interference with driver
- warning and brake intervention

Automated Highway Systems (AHS), 1997 UC Berkeley PATH

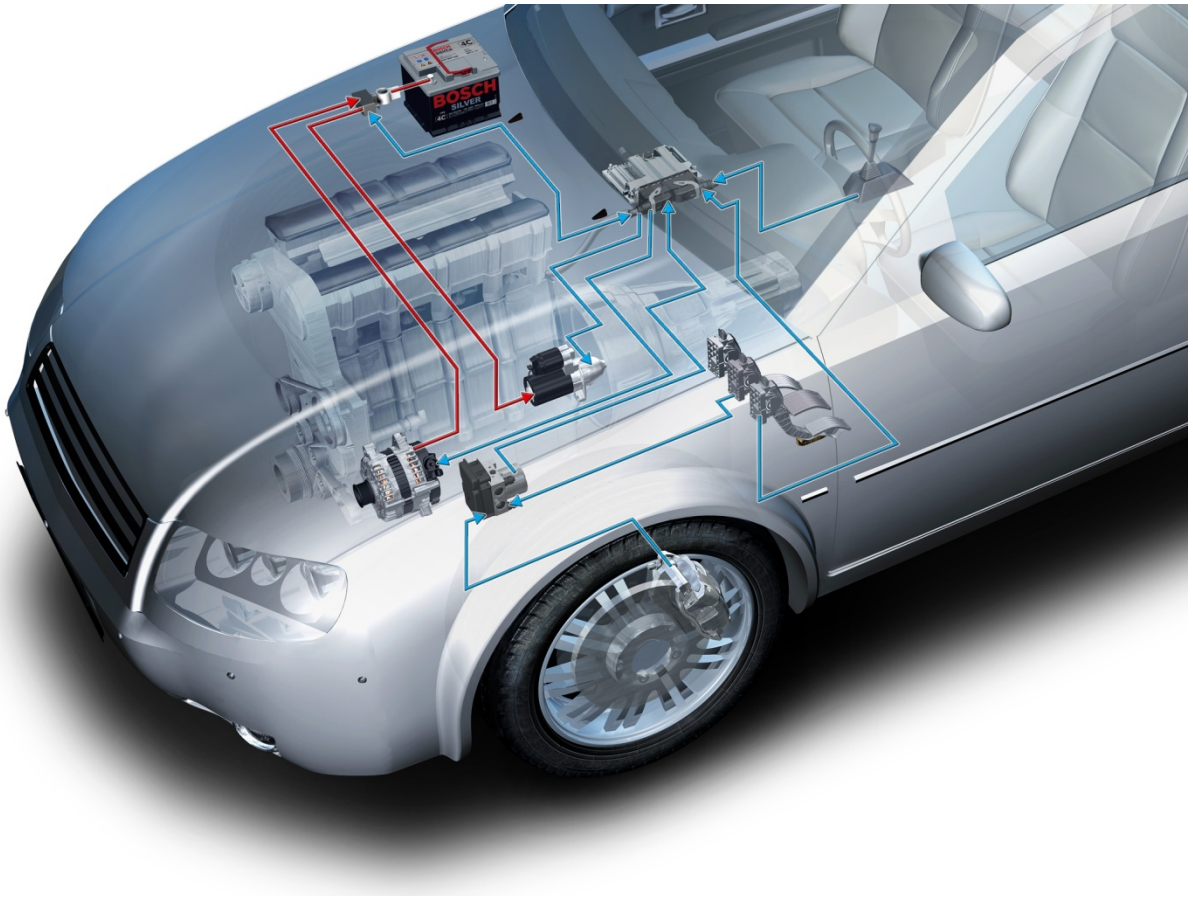
- AHS lanes will have three times the capacity of regular highway lanes - Vehicles will travel together in closely-packed “platoons”.
- Dedicated to automated vehicles - regular passenger cars will have to be specially instrumented to travel on AHS lanes.

VSC: 4 wheel independent braking

Can you brake hard on the front wheel, softly on the back left wheel and, at the same time, accelerate the back right wheel to stop the rear of your car losing control in a bend?



Bosch Start/Stop System (2008)

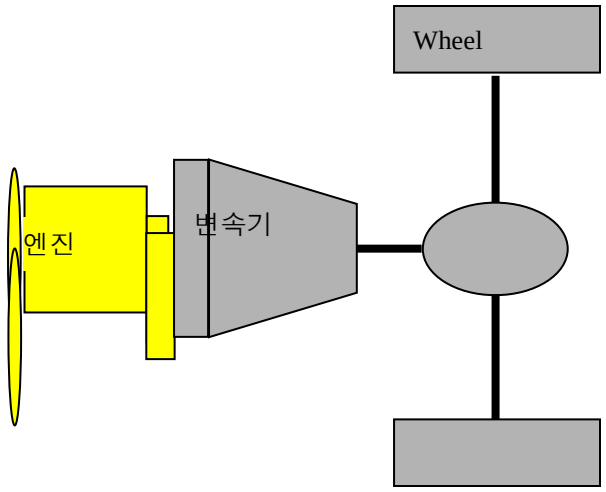


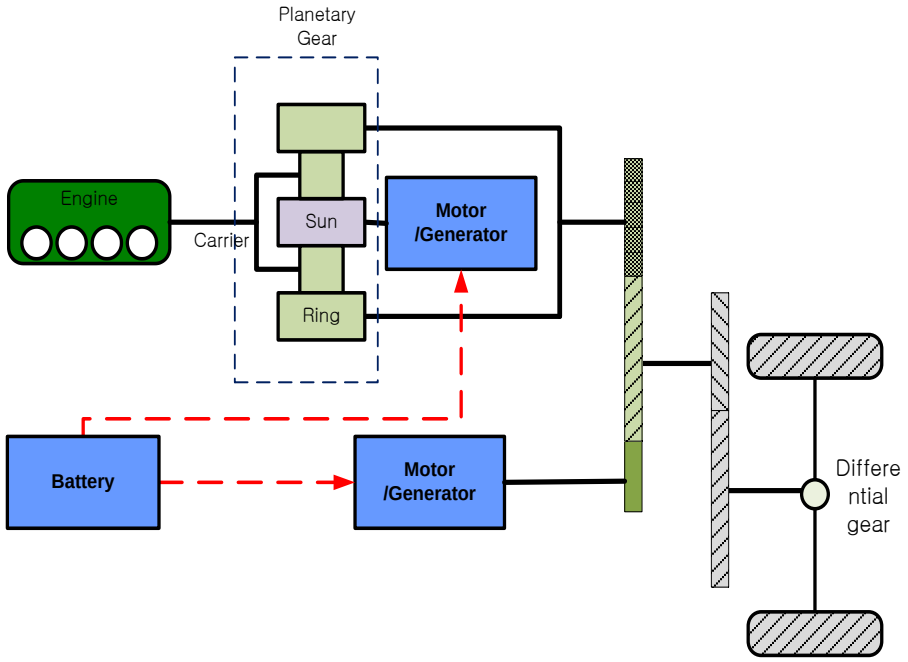
Switches off the internal-combustion engine when vehicle is at a standstill

2009 Saturn Vue 2-Mode Hybrid

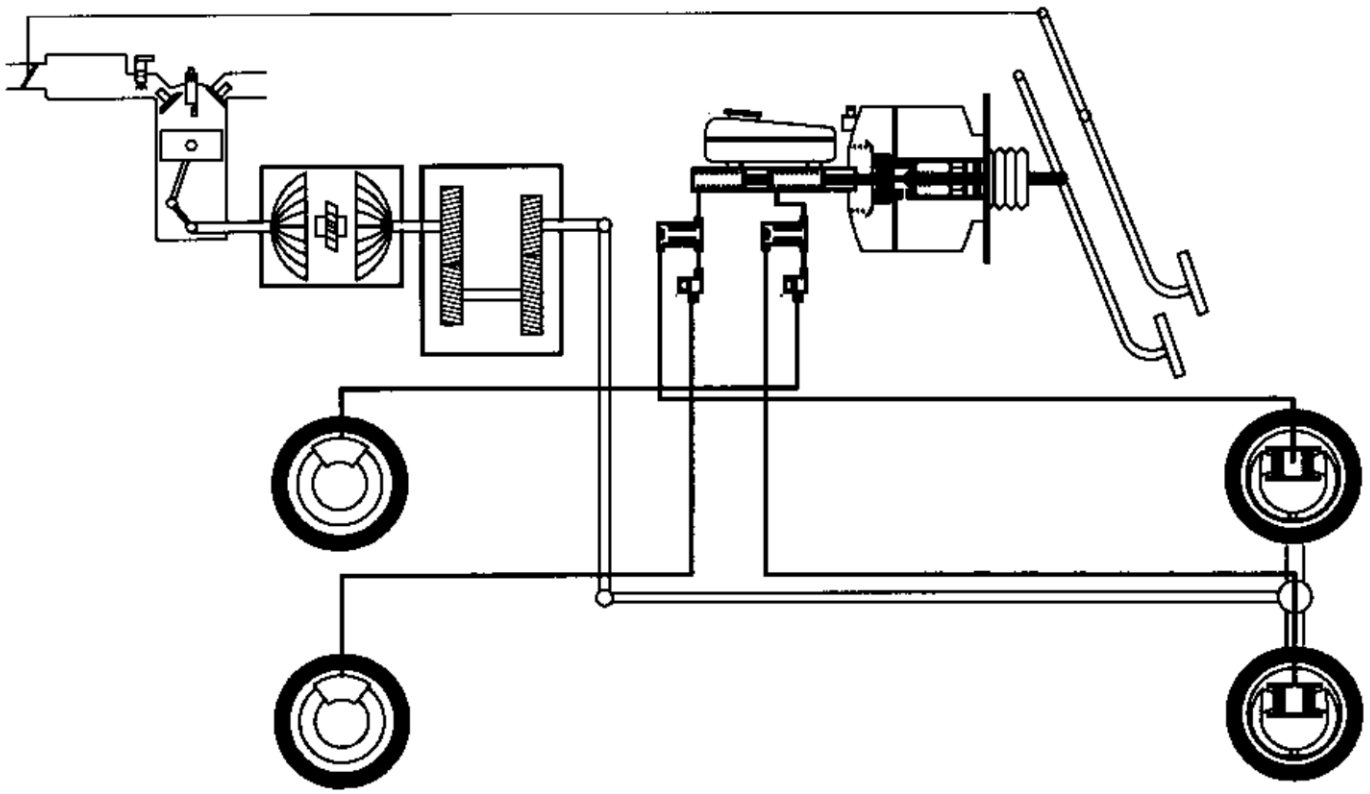
The second hybrid in the Saturn Vue range is the first application of General Motor's two-mode hybrid system for front-wheel-driver models.

Hybrid system supervisory controller development for automobile/construction vehicle applications



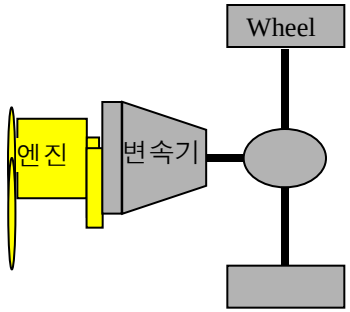


Vehicle Model:
Powertrain and Brake System

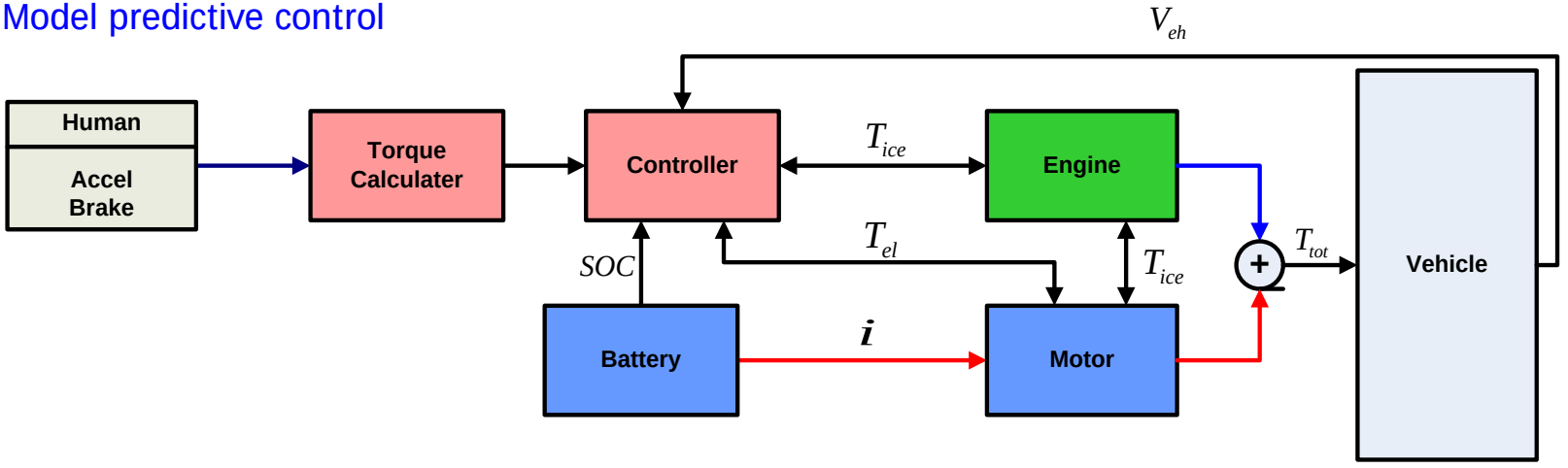


Hybrid system model and supervisory control development

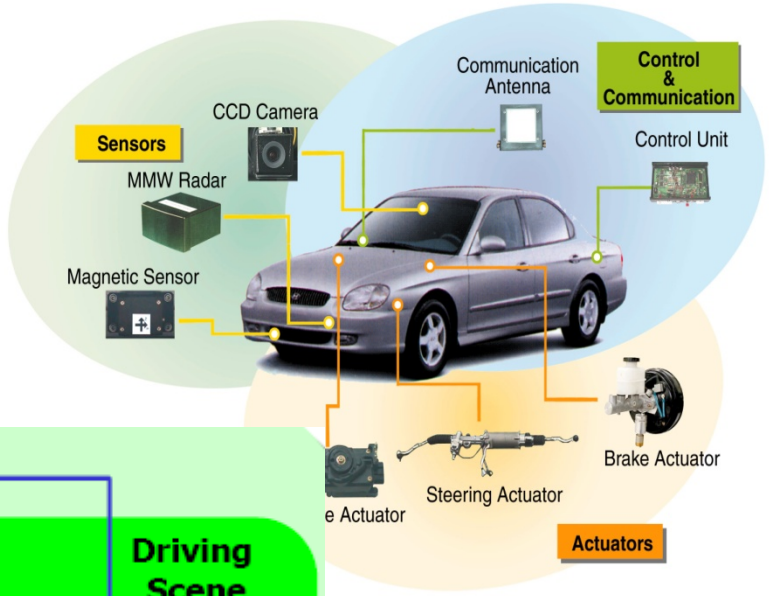
- Model and simulator development
  - Engine/powertrain/vehicle
  - Hybrid powertrain
  - Controller
  - Engine
  - Motor/Converter
  - Battery/Ultra Capacitor
  - Transmission

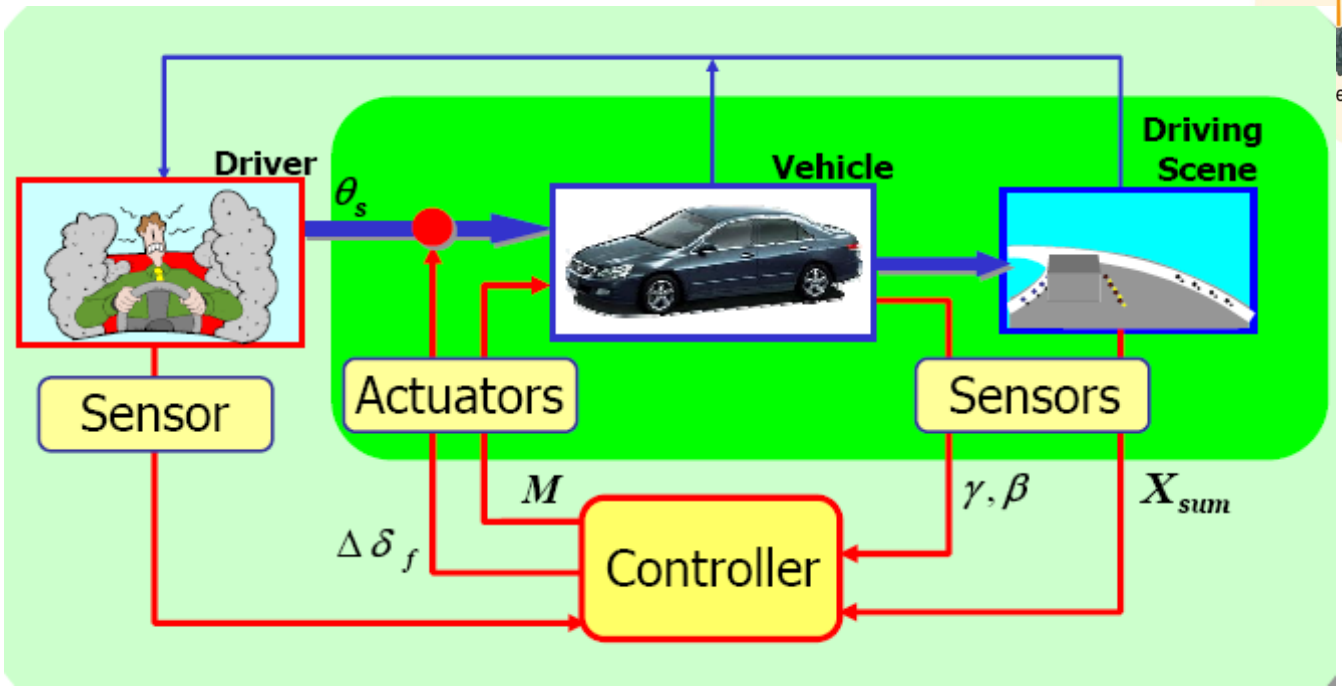


- Controller Design and Optimization
  - Supervisory/Hierarchical controller
  - Model-based design
  - Model predictive control



Vehicle Control Systems





A New generation of engine efficiency

Honda's next generation clean diesel (2008):

New technologies help to

- **maximize fuel efficiency,**
- **reduce emissions,**
- **and deliver market-pleasing performance**

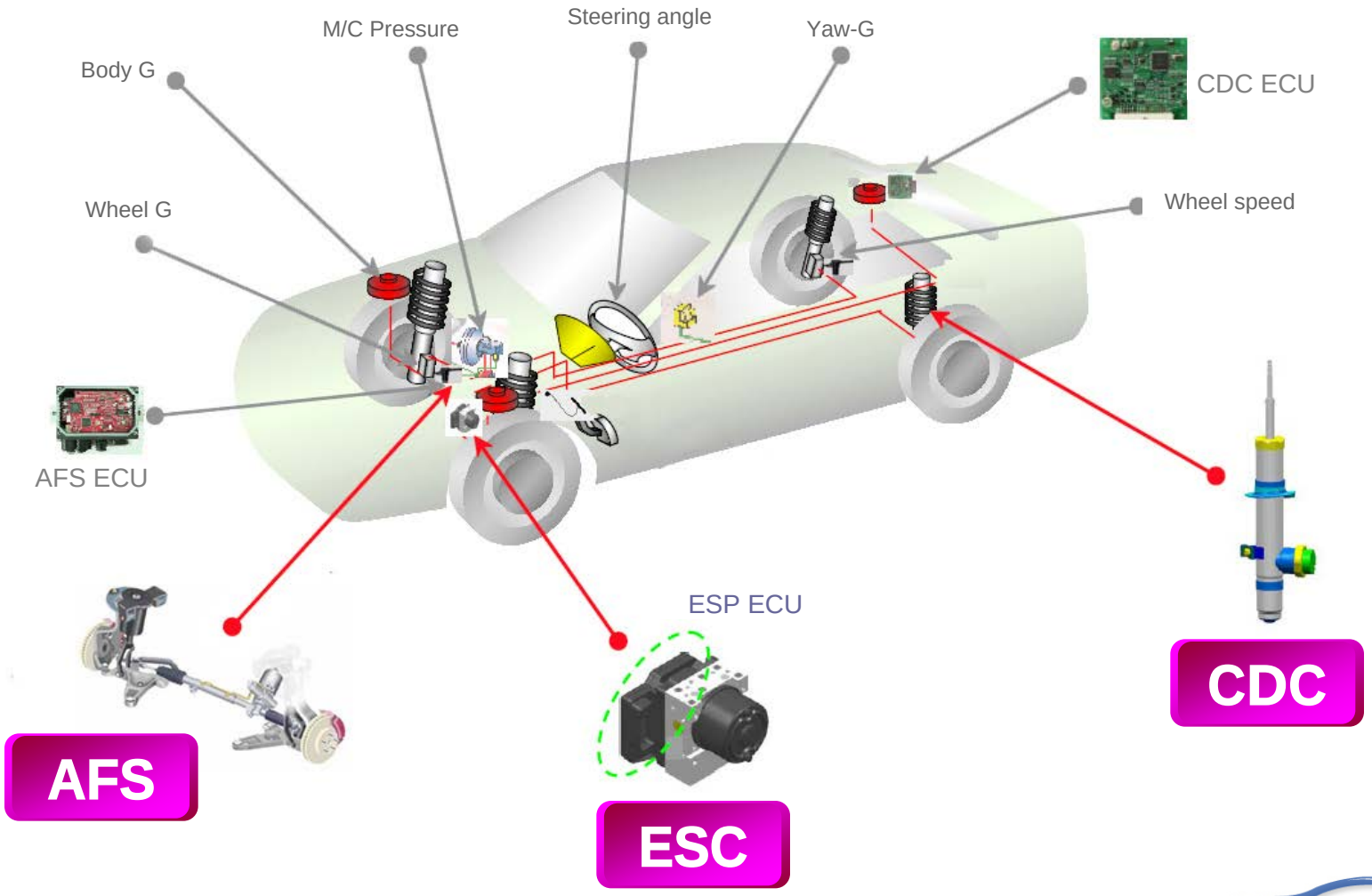
Pug-in Hybrid

Congress trying to plug in new hybrid tax credit $5,000/ vehicle up to 60,000 plug-ins.

The ford escape plug-in SUV:
- can be charged using 110- or 220-V standard household current
- takes about 6h to achieve a full charge

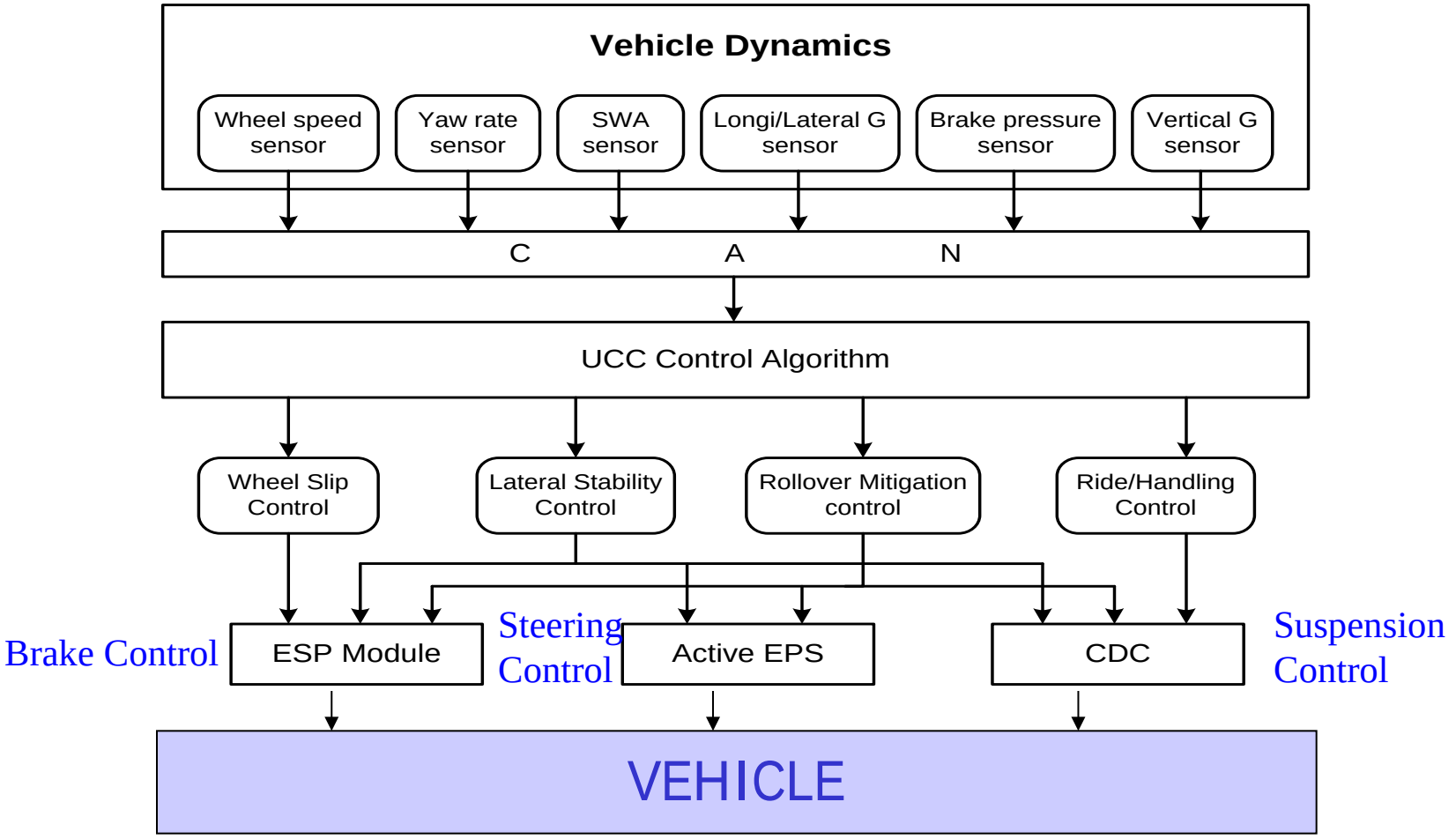
Vehicle Stability Control

Unified Chassis Control (UCC)



VDCL Vehicle Dynamics & Control Laboratory

Integrated Chassis Control

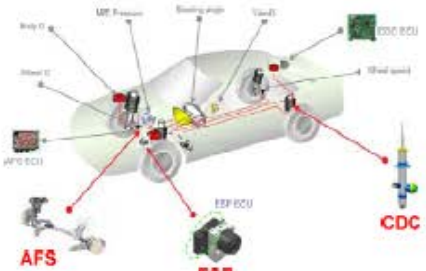


Future Intelligent Vehicle Safety Systems (IVSS)

ADAS

+

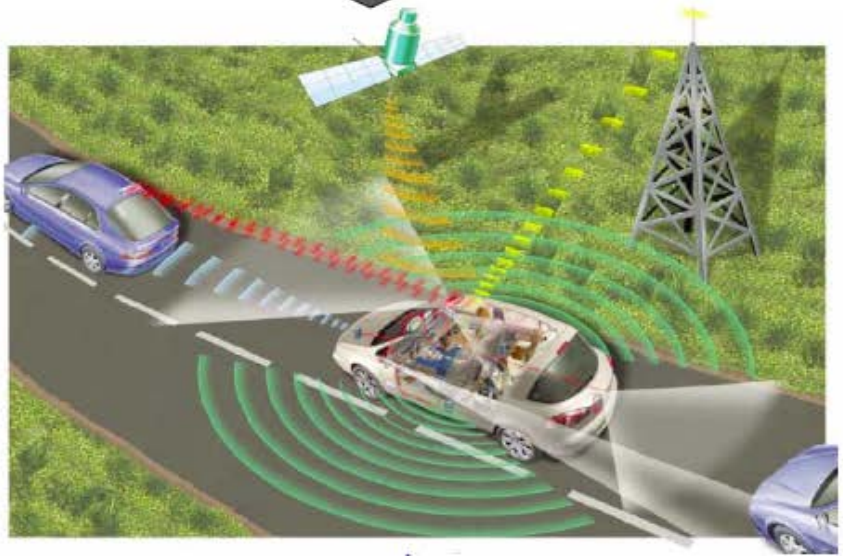
Unified Maneuverability/stability Management



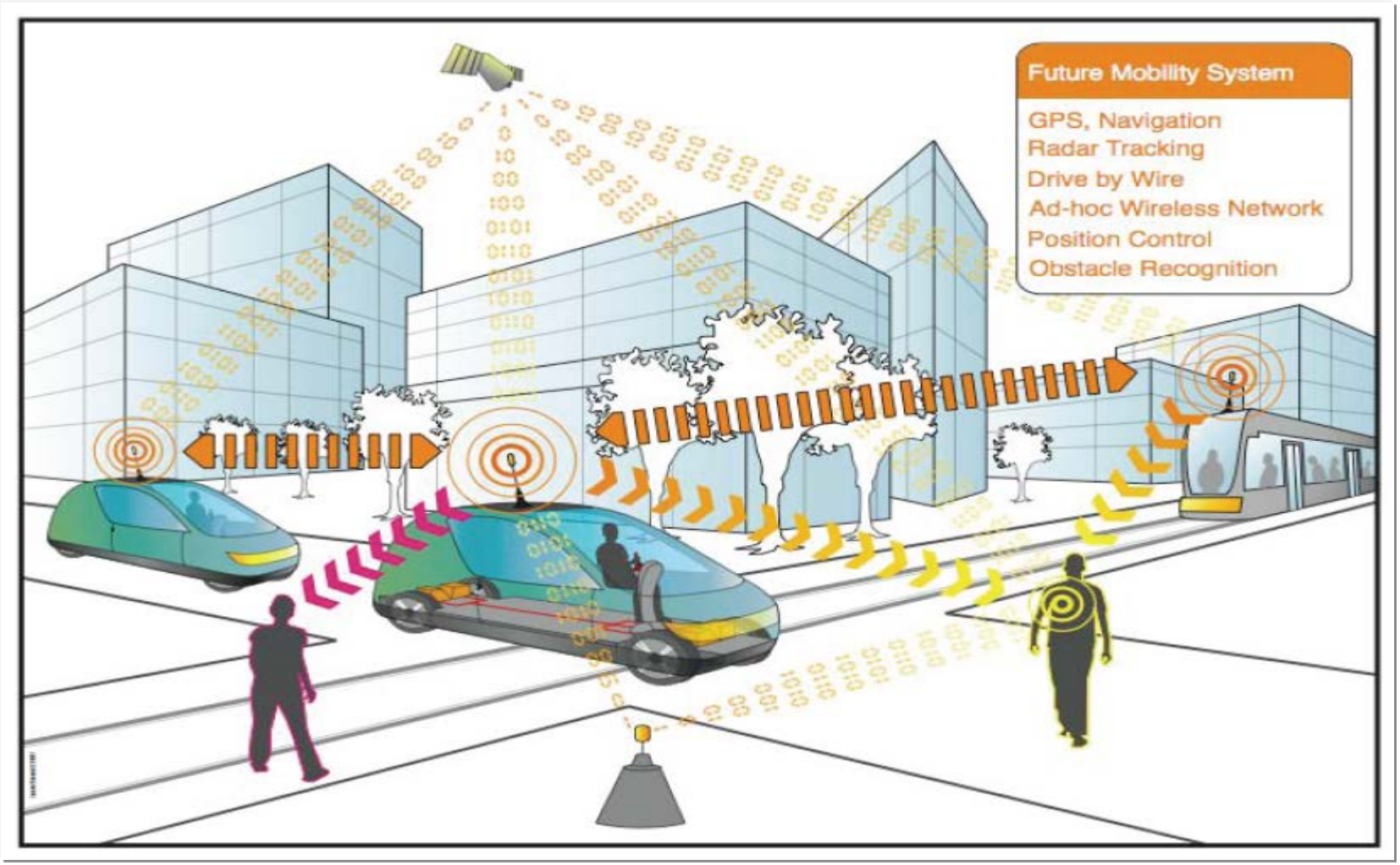
+

Infra (GPS)/x-to-vehicle communication-based Autonomous Vehicle

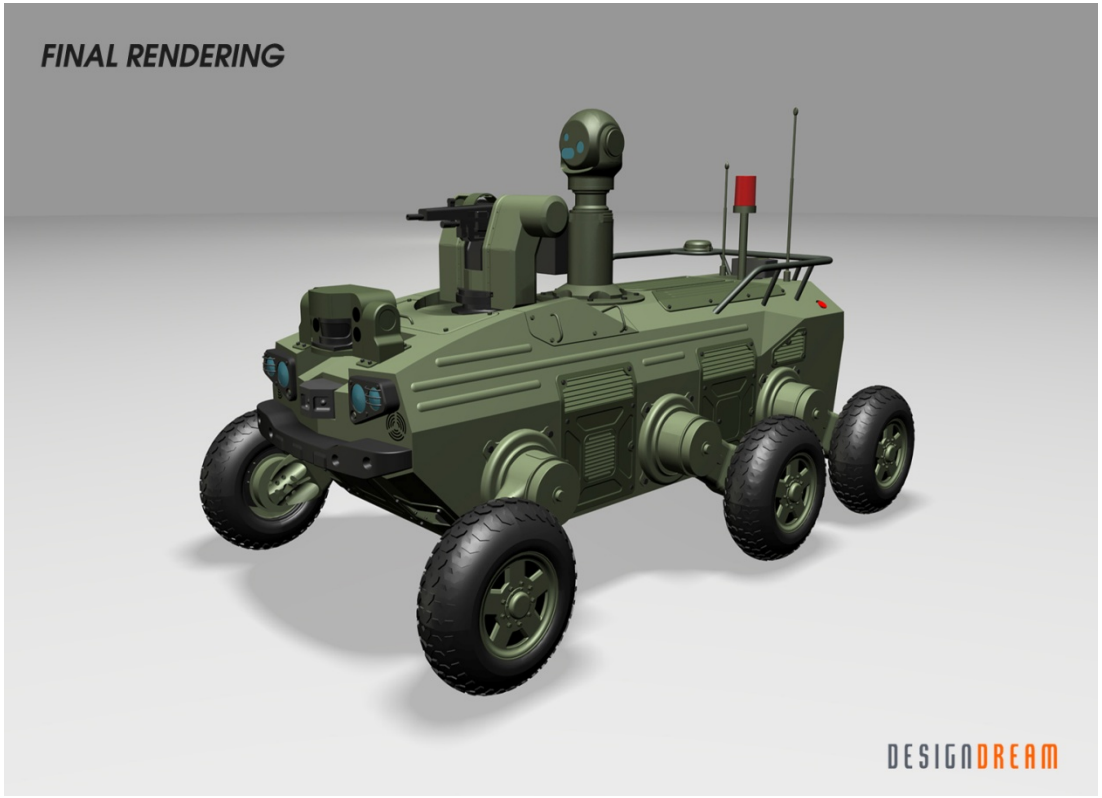
"Crash-free" Autonomous Driving with Intelligent Safety Systems



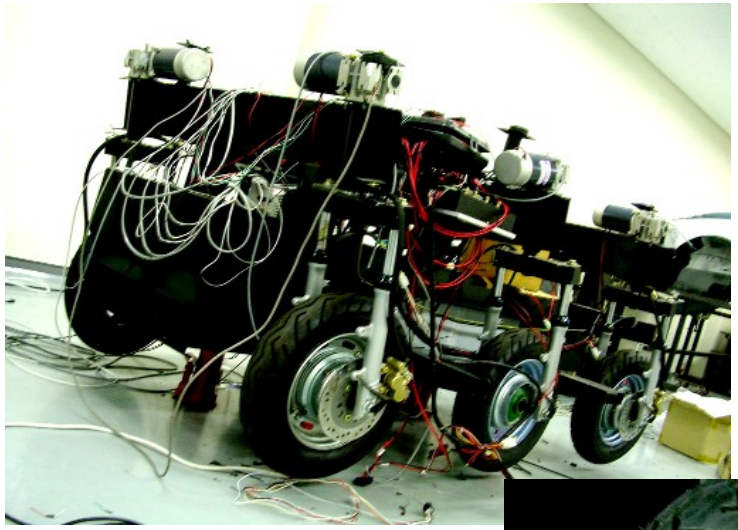
Future Mobility:
Small and smart air-cleaner

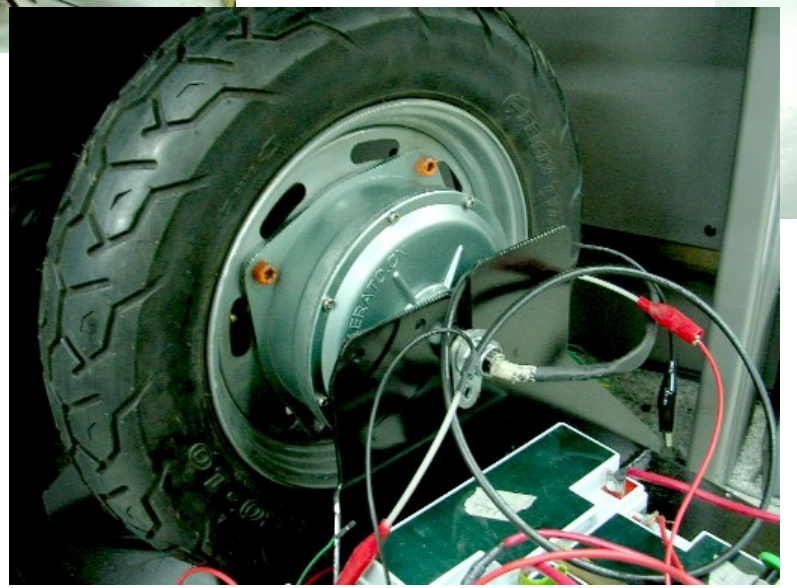


Military Robot : 견마로봇
(Autonomous Vehicle)

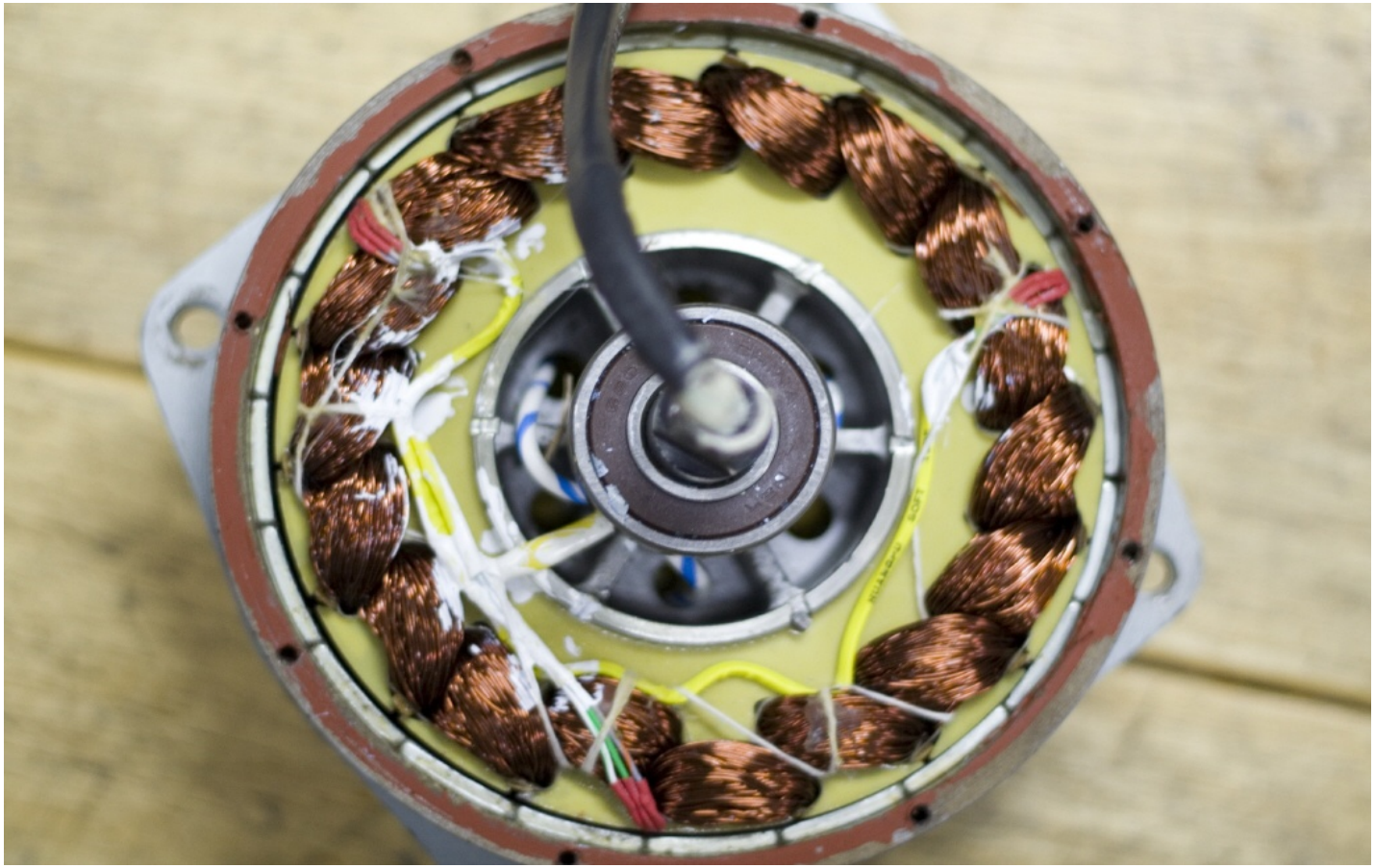


BLDC Wheel-in-Motor of 6WD6WS Vehicle





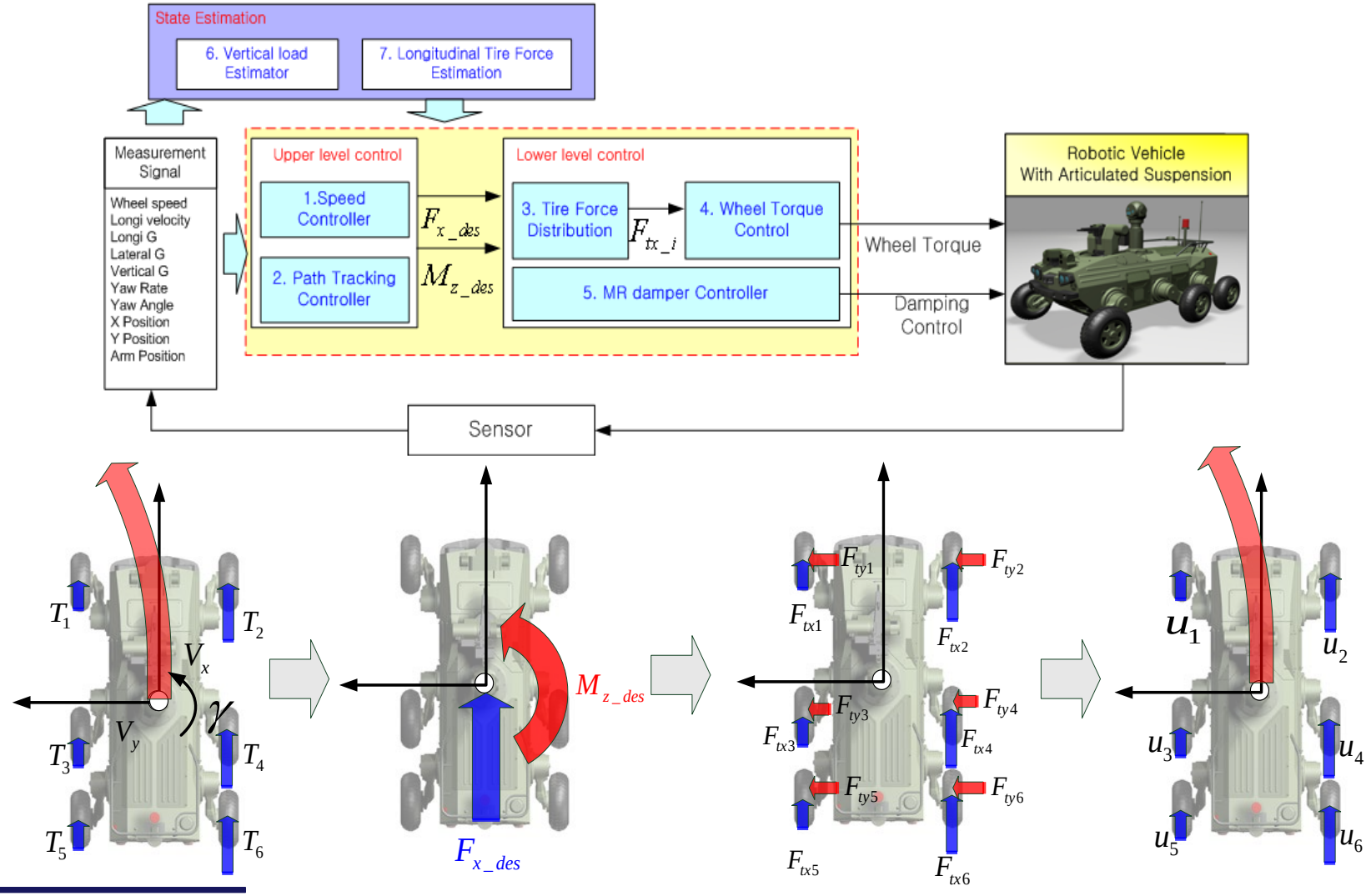
Sectional View of BLDC Motor



Autonomous Robot Vehicle

- Driving Controller for Trajectory Tracking using a Skid Steering

- Driving Controller for Trajectory Tracking



Aircraft

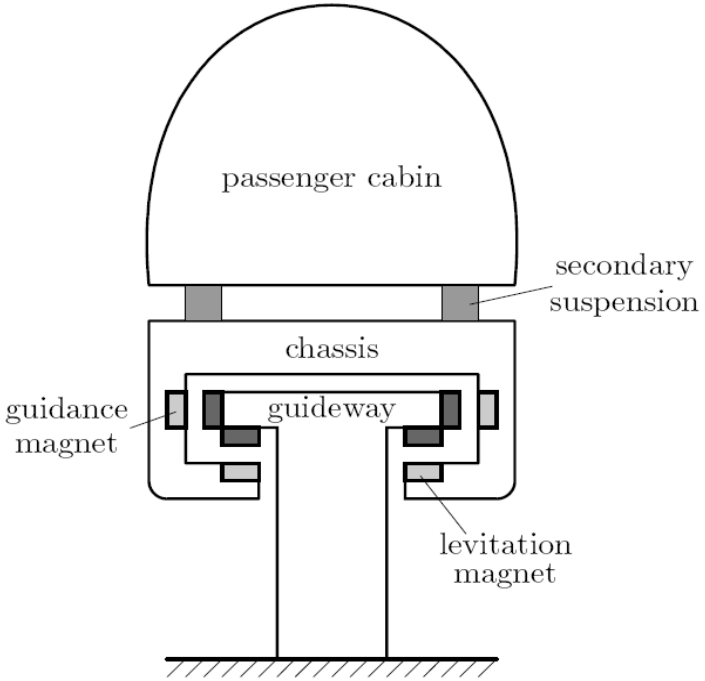
NASA x-29 forward swept wing aircraft

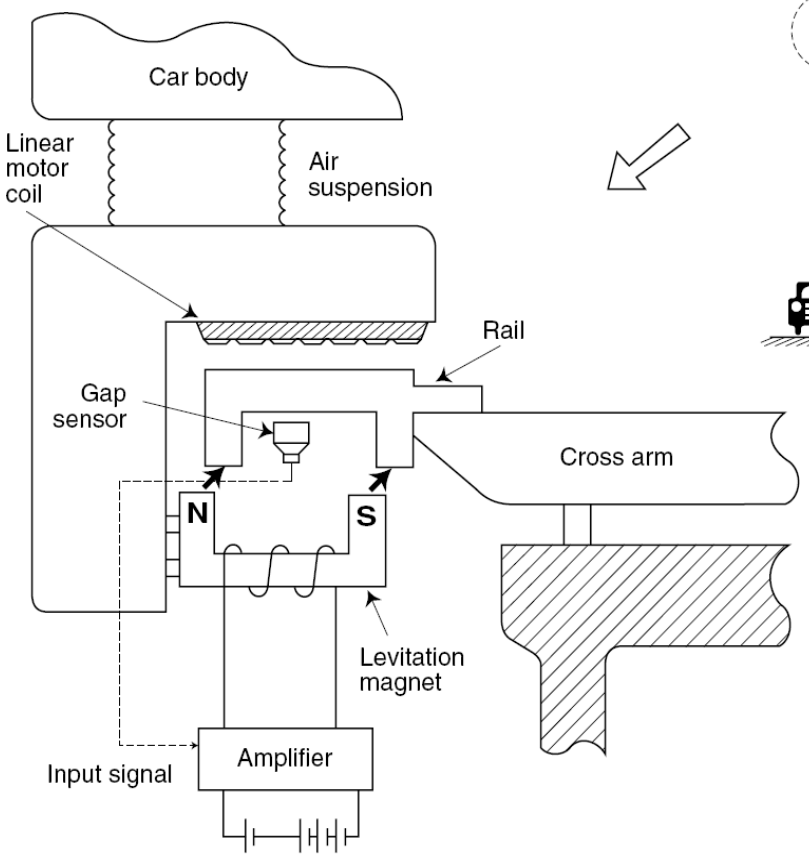
Airbus A320

Unstable

Figure 1. *Gripen JAS39 prototype accident on 2 February 1989. The pilot received only minor injuries.*


Rotem


passenger cabin
secondary suspension
chassis
guidance magnet
guideway
levitation magnet


HSST
Car body
Linear motor coil
Air suspension
Rail
Gap sensor
Cross arm
N
S
Levitation magnet
Input signal
Amplifier

Control Systems

- An aircraft
- A head positioner for a computer hard disk
- A vehicle
- An engine/transmission/brake/ steering/ suspension systems
- An electric rice cooker
- An excavator
- A room air conditioner
- A refrigerator
- Electric power plant
- Robots
- Chemical and Manufacturing Process Control: temperature; pressure; flow rate; concentration of a chemical; moisture contents; thickness.

- .....

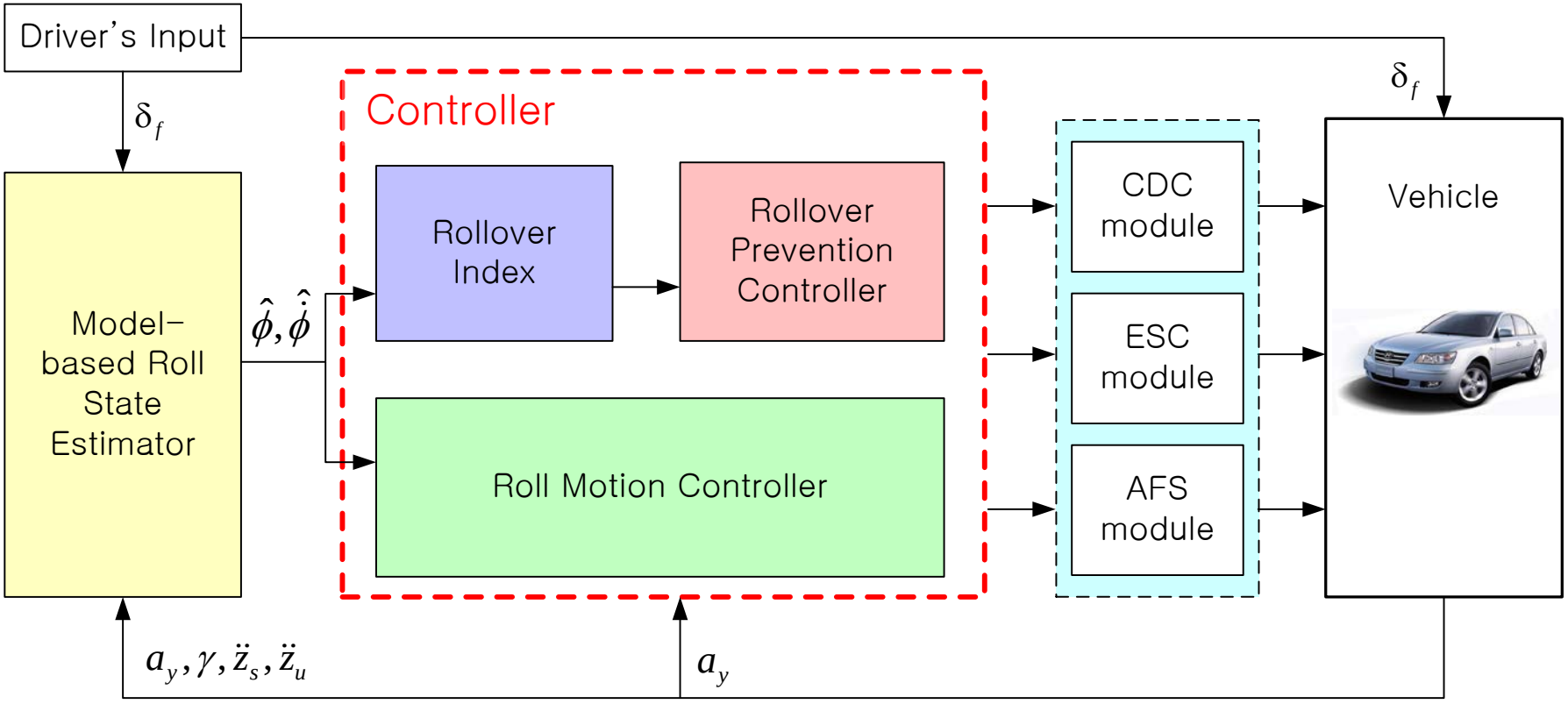
Nothing works without Control !!

To be included

- EPS/AFS
- Excavator Hybrid systems

- Vehicle Rollover Mitigation

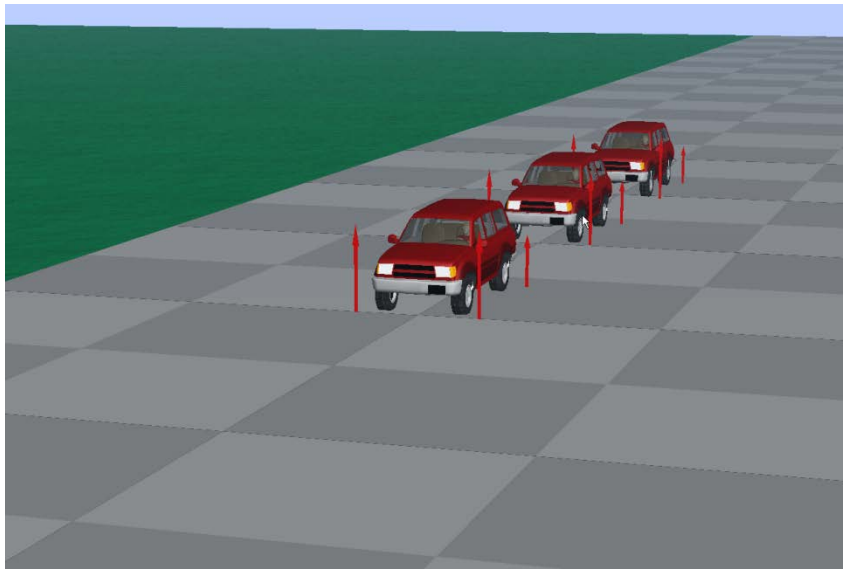
Schematic Diagram of RMC



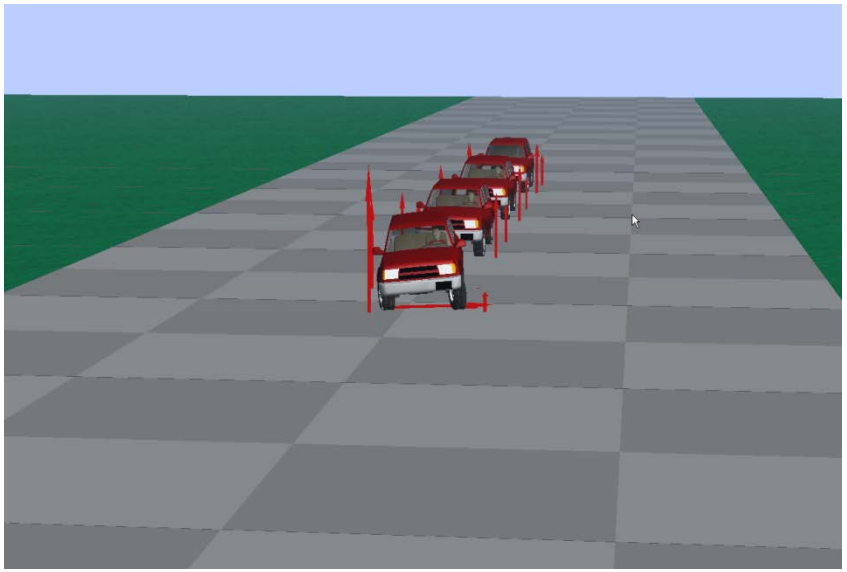
Rollover Prevention

NHTSA fishhook Simulation (CARSIM & MATLAB)

- **Without RMC**



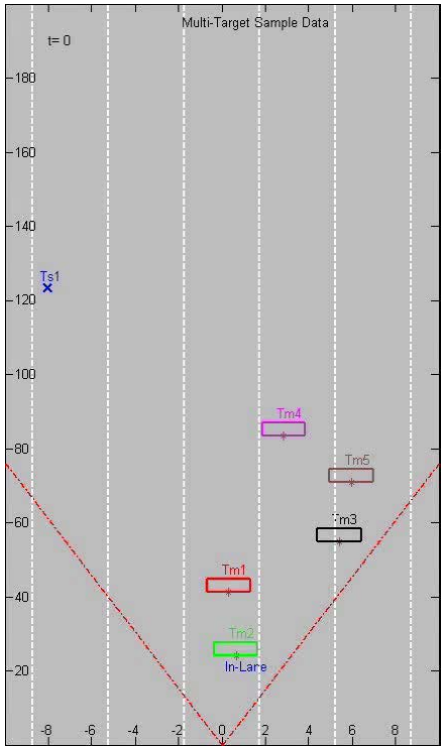
- **With RMC**



- **Autonomous Driving: Adaptive Cruise Control with Collision Avoidance**

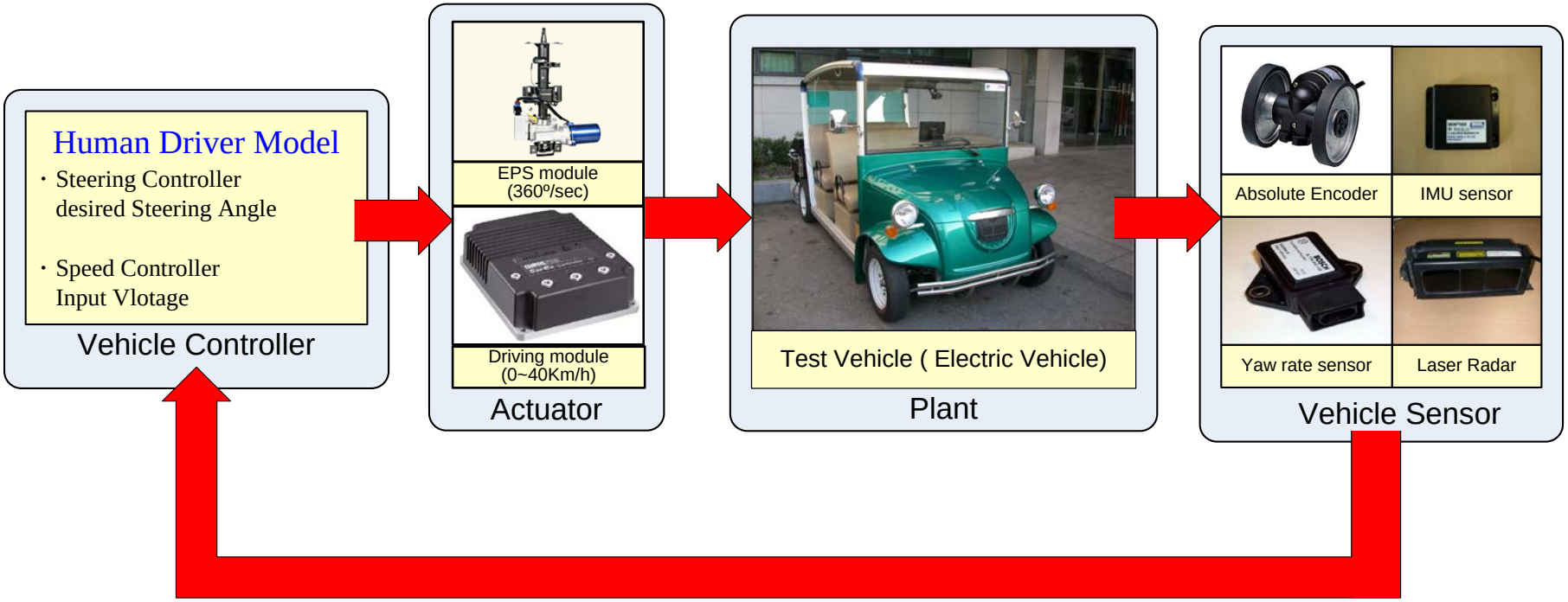
ACC/CA Vehicle

Multi-Target Detection



EV Autonomous Driving using Human Driver Model

- **System Configuration**



Vehicle Tests

- Lane Following

- Lane Following + ACC

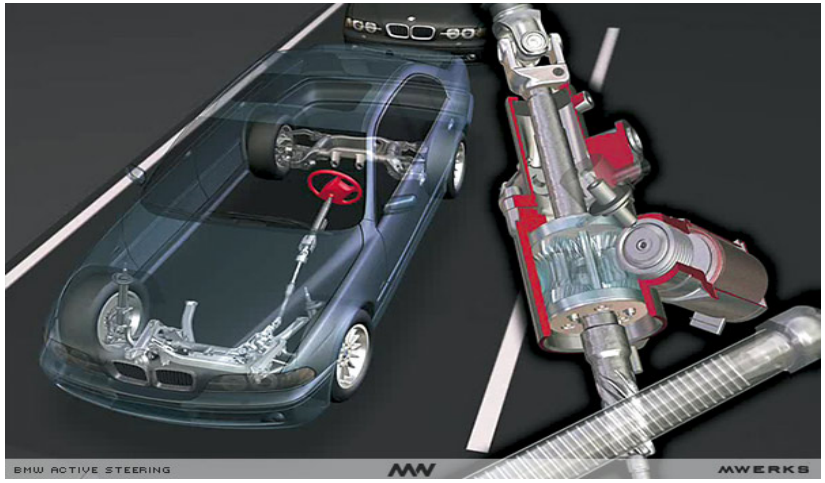
Electric Power Steering (EPS)/Active Front Steering (AFS)

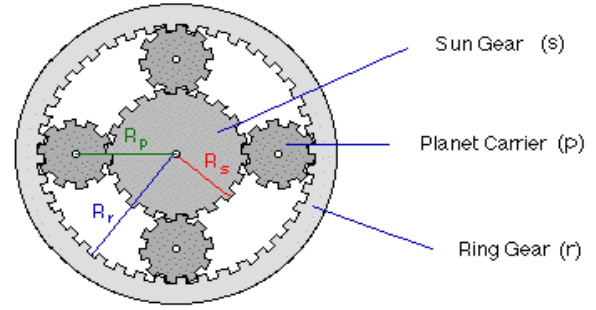
Electric Power Assist Steering

Active Front Steering AFS (control motor / Planetary Gear)

: Delphi AFS-a prototype for Cadillac CTS

: New BMW 5 series '04 (by ZF Lenksysteme)





$$2R_p\omega_p = R_s\omega_s + R_r\omega_r$$

where R: Radius
ω: Angular Velocity

Weekly Plan		
Week	Topics	comments
1	Introduction, some examples of control systems	
2	Components of a control system, modeling, Laplace transform	
3	Transfer functions	
4	Stability, step response, Routh's criterion	
5	Sensitivity, disturbance rejection	
6	Control design examples	
7	Root locus, lead and lag compensation	
8	Review and Midterm	Midterm
9	Introduction to frequency response; interpretation, bode plots	
10	Nyquist criterion, applications, gain and phase margins	
11	Design specs via loop gain, compensation, design from L	
12	Bode gain-phase relation, design case study	Design
13	Control system design example	Design
14	Control system design example	Design
15	Control term project presentation	Design example
16	Review and Final	Final Exam